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Discussion of all papers is invited

VOL. 10 MAY, 1923 No. 3

PHILADELPHIA WATER SUPPLY, PRESENT AND PROPOSED[1]

BY GEORGE W. FULLER[2]

The City of Philadelphia has an unusually interesting water plant. In point of capacity, it is one of the two or three largest plants in the world. For some twenty years it has been producing in the neighborhood of 300,000,000 gallons of water daily. During this interval the population has increased about 40 per cent and water waste has been reduced so as to maintain the supply, although the factor of safety was by no means adequate during much of the period.

In 1899 an investigation was made for betterment of the then unfiltered and highly polluted water supply. A program for filter installation was begun in 1902 and since 1912 all of the water supply has been filtered.

[1] This paper embodies the more important information set forth in the lantern slide talk at the Philadelphia Convention, May 16, 1922. In preparing this material aid has been received from the Committee on Essential Data for Water Records and Reports, Municipal Plants, on material which it is thought wise to embody in official documents of a water department. There has been some discussion as to whether such data should be put in each annual report or whether it should appear in a special publication, new editions of which would be prepared at intervals, particularly on occasions when it is necessary to go before the public in getting support for substantial programs for plant extensions and betterments.

[2] Consulting Engineer, New York, N. Y.

SOURCE OF SUPPLY

The city derives its water supply from the Schuylkill and Delaware Rivers from intakes located within the city limits. These rivers drain prosperous valleys in which there is much manufacturing, particularly in the case of the Schuylkill River, from which more than 90 per cent of the supply was derived prior to the days of filtration. Intercepting sewers along the margin of the Schuylkill protect the intakes from pollution by city sewage, but, in the valley above, the river is polluted by substantial quantities of city and industrial wastes. The latter contain phenol products and at times the city water is prejudicially affected thereby with the resulting objectionable tastes which are intensified by the application of chlorine, deemed essential for protection against water-borne diseases. The water of the Delaware is not similarly affected by industrial wastes but at the Torresdale intake its quality is affected by the discharge of city sewers, particularly at flood tides which extend to the riffles in the Delaware at Trenton.

REMEDIAL MEASURES

The city is now engaged in building an extensive system of intercepting sewers for delivering the flow of sewers now discharging into the Delaware River and for its treatment. Construction is now underway for a large sedimentation plant for the Northeast district located quite near the approach of the Delaware River Bridge of the Pennsylvania Railroad.

LOCATION OF SUPPLY WORKS

Figure 1 shows a skeleton map of the city with the locations, designated by numbers, of the principal pumping stations, filter, reservoirs and high pressure fire stations.

FILTERS

Table 1 shows type, age, size and basin capacity as well as output of the five filter plants of the city. The Torresdale plant is located adjacent to the Delaware River, while the other four filters were built at or near earlier distributing reservoirs for the Schuylkill supply. Attention is called to the load factors prepared by Mr. Van Loan for the information of his committee of this Association on "Practical Loadings for Purification Processes."

Table 2 summarizes the filter results with respect to turbidity and bacteria, while table 3 summarizes operating costs and alum doses.

The preliminary filters at the Queen Lane plant are being converted into mechanical filters.

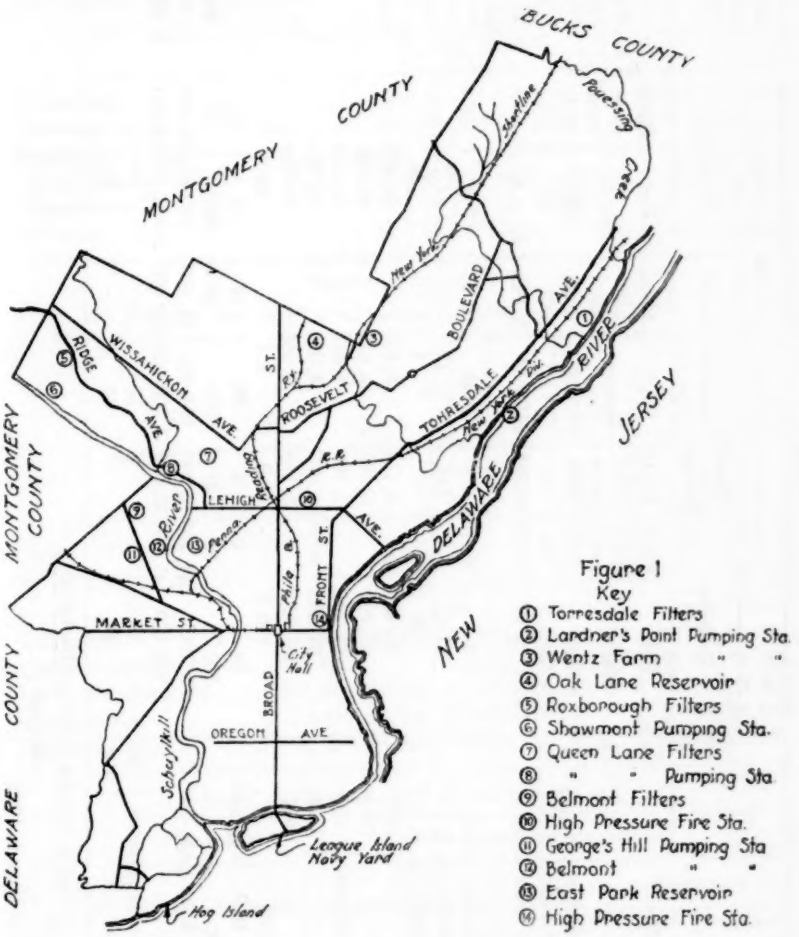


Figure 1

Key

① Torresdale Filters
② Lardner's Point Pumping Sta.
③ Wentz Farm " "
④ Oak Lane Reservoir
⑤ Roxborough Filters
⑥ Shawmont Pumping Sta.
⑦ Queen Lane Filters
⑧ " " Pumping Sta.
⑨ Belmont Filters
⑩ High Pressure Fire Sta.
⑪ George's Hill Pumping Sta.
⑫ Belmont " "
⑬ East Park Reservoir
⑭ High Pressure Fire Sta.

TYPHOID STATISTICS

Figure 2 records the typhoid fever death rate in the city during the past thirty-five years with diagrammatic record showing dates when filtered water was progressively delivered to the citizens in

TABLE 1

		STATION								
		Torresdale		Upper Roxborough	Lower Roxborough		Queen lane		Belmont	
Preliminary or final		Pre	Final	Final	Pre	Final	Pre	Final	Pre	Final
Type		Mech.	Slow sand	Slow sand	Sponge	Slow sand	Mech.	Slow sand	Coke breeze	Slow sand
Year placed in service		1909	1907	1903	1904	1902	1911	1911	1909	1904
Number of filter beds		120	65	8	11	5	40	22	18	18
Acreage	Area, each filter	20′-3″ x 16′	0.75A	0.70A	16′ x 64′	0.54A	32′ x 40′	0.71A	9–20′ x 150′	0.735A
									9–20′ x 90′	
	Total area, acres	3.4	48.75	5.6	0.26	2.7	1.2	15.6	1	13.2
Sedimentation basin, m. g.		100		147	12		177		72	
Filtered water basin, m. g.		50		8	3		50		16.5	
Million gallons filtered	1917	65,497		5,174	3,128		24,473		15,400	
	1918	65,192		5,185	3,612		22,508		16,086	
	1919	67,434		5,106	2,686		21,700		16,597	
	1920	69,350		4,975	3,052		22,251		17,006	
	1921	65,771		5,119	2,966		19,780		15,851	
Daily average, 1921		180.2		14.0	8.1		54.2		43.4	
[1] Load Factors 1921	Mean turb. (applied)	18	4	8	20	15	14	15	14	8
	Factor	950	15	20	620	45	630	5	610	26
	Mean bact. (applied)	35,100	11,100	12,900	104,000	81,400	52,600	21,000	73,100	41,200
	Factor	1,800,000	41,000	32,000	3,100,000	240,000	2,400,000	73,000	3,200,000	140,000
[2] Number of days turbidity of raw water-over	50	39			83		69		61	
	100	15			41		42		40	

[1] Load factor = $\frac{\text{m.g.d. x mean turb. (or bacteria)}}{\text{Acreage}}$

[2] May 1, 1921 to May 1, 1922.

TABLE 2

Filter results

Turbidity in p.p.m.—1921

STATION	RIVER	APPLIED PREFILTERS	REMOVED BY SEDIMENTATION BASIN	APPLIED FINALS	REMOVED BY PRELIMINARY FILTERS BASED ON		FILTERED WATER	REMOVED BY FINALS BASED ON	
					Applied	River		Applied	River
			per cent		*per cent*	*per cent*		*per cent*	*per cent*
Torresdale	23	18	21.7	4	77.8	60.9	0	100	17.4
(Average for past five years)	23	17	26.1	6	64.7	47.8	0	100	26.1
Upper Roxborough	41			8	80.5	80.5	0	100	19.5
Lower Roxborough	41	20	51.2	15	25.0	12.2	0	100	36.6
Queen Lane	40	14	65.0	5	64.3	22.5	0	100	12.5
Belmont	32	14	51.2	8	42.9	12.2	0	100	36.6

Bacteria data—1921

Bacteria per cubic centimeter—gelatin—48 hours, 20°C.

STATION	RIVER	APPLIED PRELIMINARY FILTERS	REMOVED BY SEDIMENTATION BASIN	APPLIED FINAL FILTERS	REMOVED BY PRELIMINARY FILTERS ON APPLIED	FILTERED WATER BASIN	REMOVED BY FINALS AND CHLORINE	TOTAL REMOVED BY PLANT
			per cent		*per cent*		*per cent*	*per cent*
Torresdale	44,300	35,100	20.8	11,100	68.4	4	99.96	99.99
Upper Roxborough	121,000			12,900	89.3	3	99.98	99.998
Lower Roxborough	121,000	104,000	14.0	81,000	22.1	4	99.995	99.997
Queen Lane	72,800	52,600	27.0	21,000	60.1	5	99.98	99.993
Belmont	67,900	73,100	−7.7	41,200	43.6	5	99.99	99.991

Average yearly content of B. coli per 100 cc.

YEAR	RIVER WATER		FINAL EFFLUENT FROM FILTERS				
	Delaware	Schuylkill	Torresdale	Queen Lane	Belmont	Roxborough	
						Lower	Upper
1918	670[1]	880[1]	0.70[2]	1.8[2]	2.6[2]	2.0[2]	1.4[2]
1919	590	940	0.60	3.43	2.46	2.55	2.47
1920	790	980	1.2	4.4	3.8	3.8	3.6
1921	990	980	2.1	2.3	2.0	2.1	2.0

[1] Based on 0.1 cc. tests.

[2] Based on 10 cc. tests.

[2] May 1, 1921 to May 1, 1922.

proportions depending upon the completion of the respective filter plants above described.

DISTRIBUTING RESERVOIRS

When the filter plants were built there were also installed covered distribution reservoirs for the filtered water adjacent to each of the filter plants, five in number, as shown in table 4. The Oak Lane

TABLE 3

Filter statistics

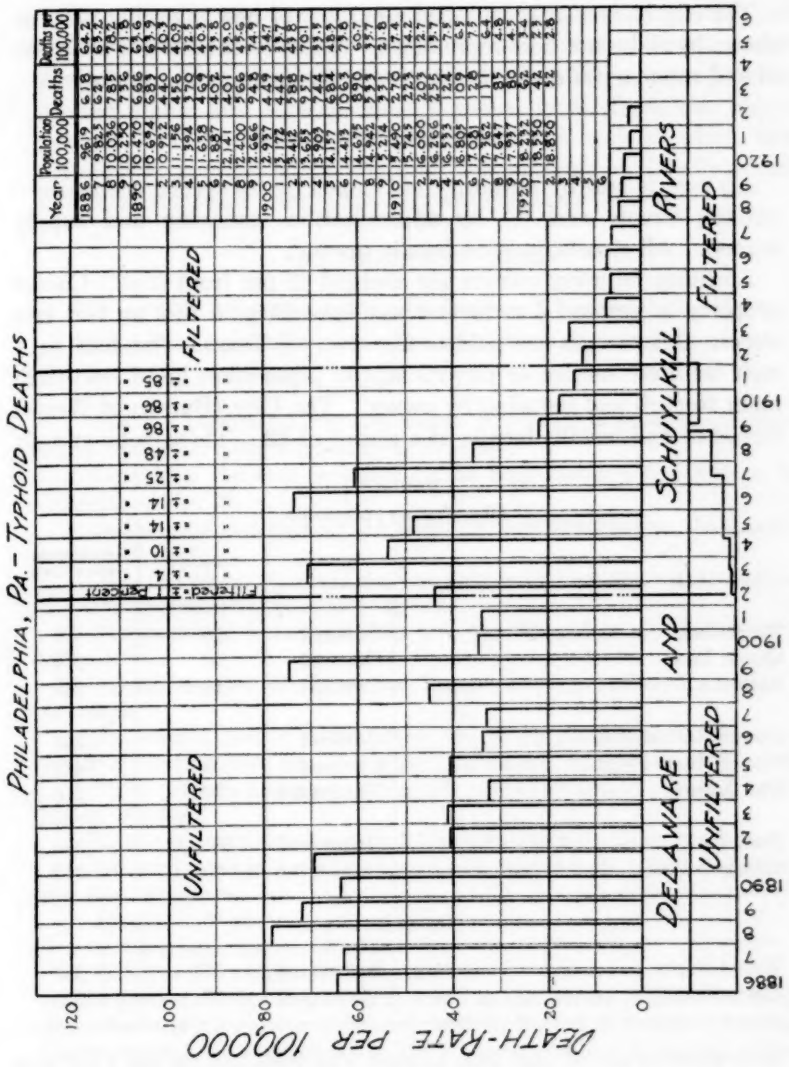
Operating cost for 1921

	BELMONT		QUEEN LANE		ROXBOROUGHS		TORRESDALE	
	1920	1921	1920	1921	1920	1921	1920	1921
Pre filters (dollars)	35,947	38,827	33,489	40,681	11,276	6,415	46,086	66,140
Final filter (dollars)	61,207	78,830	58,261	61.019	41,713	48,719	117,555	154,326
Total cost (dollars)	97,154	117,656	91,750	101,700	52,989	55,134	163,641	220,466
Million gallons filtered	17,006	15,854	22,251	19,947	8,027	8,086	67,434	65,768
Cost per million gallons (dollars)	5.71	7.42	4.12	5.09	6.60	6.82	2.42	3.34

Alum application

	DELAWARE RIVER—TORRESDALE			SCHUYLKILL RIVER—QUEEN LANE		
	Treated	Average actual dosage	Average for year	Treated	Average actual dosage	Average for year
	per cent	*grains*	*gallons*	*per cent*	*grains*	*gallons*
1917				9.3	2.00	0.19
1918	4.5	1.54	0.07	6.0	1.49	0.09
1919	3.5	1.55	0.05	4.3	2.10	0.09
1920	4.6	1.64	0.08	5.8	1.75	0.10
1921	5.8	1.69	0.10	7.5	2.2	0.15

reservoir for the storage of filtered water from the Torresdale plant was also built. This reservoir was provided with footing courses for piers but covers were not built. Prior to filtration there were four uncovered distributing reservoirs, all at comparatively low elevation and of which two have been out of service for some time. The East Park reservoir is held for emergency use chiefly.


PHILADELPHIA, PA. – TYPHOID DEATHS
DEATH-RATE PER 100,000
DELAWARE AND SCHUYLKILL RIVERS
UNFILTERED
FILTERED
UNFILTERED
FILTERED
Filtered: Percent
85
86
86
48
25
14
14
10
4
Year | Population 100,000 | Deaths | Deaths per 100,000
1886 | 9619 | 618 | 64.2
7 | 9.825 | 621 | 63.2
8 | 10.036 | 785 | 78.2
9 | 10.250 | 736 | 71.8
1890 | 10.470 | 666 | 63.6
1 | 10.694 | 683 | 63.9
2 | 10.922 | 440 | 40.3
3 | 11.152 | 456 | 40.9
4 | 11.619 | 462 | 40.3
5 | 11.887 | 402 | 33.8
6 | 12.141 | 401 | 33.0
7 | 12.400 | 566 | 45.6
8 | 12.666 | 948 | 74.9
9 | 12.937 | 449 | 34.7
1900 | 13.178 | 444 | 33.7
1 | 13.412 | 588 | 43.8
2 | 13.655 | 977 | 70.1
3 | 13.905 | 1.244 | 89.3
4 | 14.197 | 1.684 | 118.5
5 | 14.419 | 1.065 | 73.6
6 | 14.692 | 870 | 59.7
7 | 14.914 | 431 | 21.8
8 | 15.214 | 270 | 17.4
9 | 15.490 | 223 | 14.2
1910 | 15.745 | 203 | 12.7
1 | 16.000 | 255 | 15.7
2 | 16.266 | 124 | 7.5
3 | 16.555 | 109 | 6.5
4 | 16.805 | 128 | 7.5
5 | 17.091 | 110 | 6.4
6 | 17.362 | 85 | 4.8
7 | 17.647 | 80 | 4.5
8 | 17.925 | 75 | 4.2
1920 | 18.222 | 42 | 2.3
1 | 18.540 | 42 | 2.2
2 | 18.850
3
4
5
6

STEAM PUMPING EQUIPMENT

The city has recently installed a number of new pumping units as shown by slides not here reproduced. Table 5 contains a description of and summary of coal consumption at the main pumping stations.

DISTRIBUTION PIPE SYSTEM

All pipe is laid by authority of Council by (*a*) special ordinance—naming streets and (*b*) by appropriation (pumping and supply mains). All streets must be legally opened.

Abutting property owners are charged $2 per front foot. Corner property is granted ⅓ reduction not exceeding 50 feet on last laid street. All charges are paid to Receiver of Taxes. One-half to 2 inch inclusive service or private supply pipes must be of lead from main to curb and installed by owner. The City (Bureau of Water) furnishes and installs ferrule at a charge of $2. Three, four and six

TABLE 4

Distributing reservoirs

LOCATION	COVERED	CAPACITY	ELEVATION FLOW LINE
		million gallons	
Torresdale	Covered	50	7
Queen Lane	Covered	40	216
Belmont	Covered	16.5	239
Lower Roxborough	Covered	3	326
Upper Roxborough	Covered	8	410
Oak Lane	Uncovered	70	210
East Park	Uncovered	688	133
George's Hill	Uncovered	40	212
Not in service			
Wentz Farm	Uncovered	37	167
Corinthian	Uncovered	37	120

inch services are of cast iron to curb and installed by the City at a charge of $50, $60 and $75 respectively. A permit to open the street must be secured by the owner from the Bureau of Highways at a charge of $20 for paved streets and a nominal charge for unpaved streets.

HIGH PRESSURE FIRE SYSTEM

The system has two high pressure fire systems of which the Race Street Station on the Delaware River was installed about twenty years ago. There is also a newer plant about ten years old taking filtered water and located some distance north from the central part of the City. The main features of these systems which were installed on account of the relatively low pressure of the city supplv and in a congested part of the city are shown in table 6.

FIRE PROTECTION RATING

During 1922 a survey and report was made by the National Board of Fire Underwriters of the more important features as shown in the following summary:

1. Out of a possible total of 1700 points of demerit in grading, the entire water supply was given a deficiency of 84 points.
2. Outside of the zone protected by the High Pressure Fire System, the demerits totaled 391.
3. In the zone protected by the High Pressure Fire System, the demerits totaled 30.
4. Allotting proper weight to these respective districts, the water supply for the City as a whole was penalized 84 points.
5. The principal factors entering into the 391 points of demerit are as follows:

a. Fire hydrant pressure lower than 75 pounds over a considerable territory, 48 points.

b. Fairmount Dam, a wooden structure which the Board of Consulting Engineers recommends replacing with a permanent masonry dam, 36 points.

c. Three (3) large and important supply mains laid side by side in the same street, 18 points.

d. Deficiency in fireproof construction at Pumping Stations, 21 points.

e. Gridiron system not exceeding 6-inch and 8-inch pipes, in built-up sections, 149 points.

f. Dead ends, 15 points.

g. Old type gate valves, 15 points.

h. Old type fire hydrants, 12 points.

The general system of grading followed in this survey is described in the Journal of this Association of January, 1922, by Robert E. Andrews, Assistant Chief Engineer, National Board of Fire Underwriters, San Francisco. Quoting from that paper:

TABLE 5

Pumping machinery—Steam

Bureau of Water, Philadelphia; at beginning of 1922

STATION	DESCRIPTION					WORKING CONDITIONS			
	Number of units	Year installed	Builder	Type		Rated capacity m.g. per 24 hours	Steam pressure per sq. inch	Vacuum in mercury	Total head
				Steam end	Water end				
							lbs.	*inches*	*feet*
Belmont	2	1916	De Laval	Turbine	Centrifugal	22	190	28	316
	2	1908	Bethlehem	Hor. cross comp.	Double plunger	10	150	26	316
	1	1900	Holly	Hor. comp.	2 Plunger	10	150	27	316
	1	1895	Worthington	Duplex comp.	2 Plunger	20	100	24	316
Queen Lane	1	1917	De Laval	Turbine	Centrifugal	25	175	28	271
	2	1921	De Laval	Turbine	Centrifugal	40	175	28	271
Shawmont	1	1887	Gaskill	Hor. comp.	2 Plunger	10	100	24	400
	2	1908	Snow	Hor. cross comp.	2 Plunger	5	150	26	400
	1	1916	Southwark	Turbine	Worth-Cent.	10	150	28	400
	1	1917	Southwark	Turbine	Worth-Cent.	10	150	28	400
	1	1918	Southwark	Turbine	Worth-Cent.	10	150	28	400
Ld's Pt. 2....	6	1903	Holly	Vert. trip. exp.	3 Plunger	20	150	28	184
Ld's Pt. 3....	4	1908	Holly	Vert. trip. exp.	3 Plunger	20	175	28	253
Ld's Pt. 3....	2	1909	Holly	Vert. trip. exp.	3 Plunger	30	175	28	184
Ld's Pt. 4....	1	1918	De Laval	Turbine	Centrifugal	35	175	29	184
Torresdale	6	1907	Ames Engines R. D. Wood Pumps	Vert. uniflow	Centrifugal	40	175	26	42
	1	1908	Bates Engine Allis Chalmers pump	Vert. cross comp.	Centrifugal	40	175	26	42
	1	1910	De Laval	Turbines	Centrifugal	50	175	26	42

Torresdale	1	1908	Bates Engine						
	1	1910	Allis Chalmers pump De Laval	Vert. cross comp. Turbines	Centrifugal Centrifugal	40 50	175 175	26 26	42 42

1921 annual operating data

STATION	PUMPAGE M.G.	MEAN HEAD (FEET)	COAL (TONS)	MILLION FT. LBS. PER 100 LB. COAL	COST PER M.G. 100 FT.
Belmont	17,596	296	34,809	60.8	5.67
Queen Lane	21,322	271	36,218	57.4	5.27
Shawmont	8,896	393	24,550	54.4	9.48
Ld's Pt	64,595	202	84,615	63.7	6.37
Torresdale	69,204	43	43,088	29.2	13.41

Approximate b.t.u. per lb. coal—12,000.

TABLE 6

High pressure fire system

STATION		RACE ST.	FAIRHILL
WATER SUPPLY		Delaware river	5 m.g. basin (filtered water)
Length of mains	20 inches	1.0-mile	7.5-miles
	16 inches	1.2-miles	5.5-miles
	12 inches	5.5-miles	10.5-miles
	8 inches	8.0-miles	8.5-miles
	Total	15.7-miles	32.0-miles
Power	Gas engines—300 h.p.	7	10
	(3 cyl. vertical)—125 h.p.	2	1
Pumps triplex-double acting	Speed-r.p.m.	40	40
	No. 1200 g.p.m.	7	10
	No. 350 g.p.m.	2	1
	Total capacity-station-g.p.m.	9100	12,350
No. of hydrants		289	600
Normal pressure when not in service		15 to 45 lbs.	10 to 45 lbs.
Pressure of fire service		175 to 300 lbs. as ordered	

	1921	1920	1921	1920
Services	39	35	8	15
No. of service calls	209	166	268	270
Total	248	201	276	285

Total-both stations	1920—486 1921—524	
Cost: Ground	$130,000	Old resevoir site
Building	90,000	$150,000
Engines and pumps	180,000	250,000
Mains	480,000	1,750,000
Total	880,000	2,150,000
Total-both stations	$3,030,000	
Cost of operating, year 1921: Labor	$81,011.38	
Other cost	8,879.04	
Total	$89,890.42	

The plan adopted is like that of marking a school-boy's examination paper, where so much is taken off for every mistake. The sum of the maximum points of deficiency totals 5000 and is divided in accordance with the relative values of the features as follows:

	MAXIMUM POINTS	PHILADELPHIA SURVEY
Water Supply	1700	84
Fire department	1500	227
Fire alarm	550	171
Police	50	
Building laws	200	28
Hazards	300	64
Structural conditions	700	
Total	5000	

FINANCIAL DATA

In table 7 is given a summary of recent revenue statements of the City Water Bureau together with minimum meter rates and the quantities of water allowed therefor. Attention is called in this connection to the fact that the distribution pipe system is paid for largely by assessment and also to the fact that all water passed through a meter in excess of the minimum quantity allowed for each size and connection is charged at a uniform rate.

NEW SOURCES OF SUPPLY

In 1920, an investigation was made of extensions and improvements of the present city water works system by a Board of Consulting Engineers, consisting of J. W. Ledoux, Chairman, George W. Fuller, Joseph F. Hasskarl, J. Waldo Smith. Figure 3 shows the location of various watersheds considered by this Board, which reported conclusions and recommendations as follows:

1. The present sources of supply at local points on the Delaware and Schuylkill Rivers must of necessity be continued for a time and, barring occasional tastes due to industrial drainage, can be made to furnish a safe and adequate supply.

2. Extensive improvements and additions must be made to the present works at once in order to insure an ample quantity at a reasonable pressure and of a satisfactory quality throughout the entire City. This requires extensive changes in and additions to

TABLE 7

Financial statement

	1921	1920	1919
Total revenue	$6,222,872.06	$6,523,240.36	$6,209,678.00
Per inhabitant	3.33	3.55	3.43
Per mile of pipe	3,219	3,414	3,274
Per 1,000 gallons	$0.057	$0.056	$0.055
Per cent sales from:			
Metered services	45.4	48.1	44.0
Unmetered services	54.6	51.9	56.0
Revenue from:			
City departments	0	0	0
Fire protection	0	0	0
Discount to charities	Averages 90 per cent—equivalent to about $130,000 annually		
Services	Total 388,000; metered 88,000; per cent metered, 23		
Total operating expense: inc. high pressure fire	$3,711,584.06	$3,766,059.73	$3,210,799.16

Minimum meter rates and quantities of water allowed therefor

	minimum	*cubic feet*
For ½ inch ferrule	$8.00	8,000
For ⅝ inch ferrule	12.00	12,000
For ¾ inch ferrule	18.00	18,000
For 1 inch ferrule	32.00	32,000
For 1¼ inch ferrule	50.00	50,000
For 1½ inch ferrule	75.00	75,000
For 2 inch ferrule	130.00	130,000
For 3 inch ferrule	290.00	290,000
For 4 inch ferrule	515.00	515,000
For 6 inches ferrule	1,150.00	1,150,000

All water in excess in any year of the quantity hereinabove fixed for any metered connection shall be charged for at the rate of forty (40) cents per one thousand (1000) cubic feet.

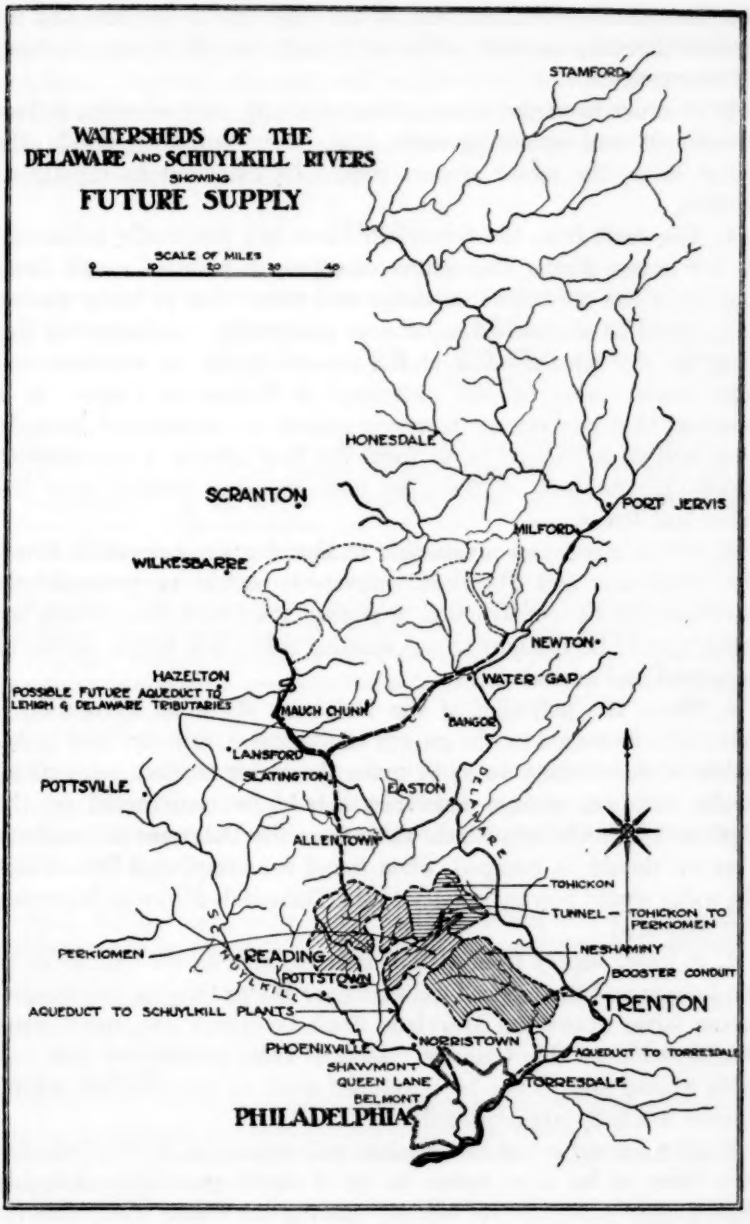

WATERSHEDS OF THE
DELAWARE AND SCHUYLKILL RIVERS
SHOWING
FUTURE SUPPLY
SCALE OF MILES
0 10 20 30 40
STAMFORD
HONESDALE
SCRANTON
PORT JERVIS
MILFORD
WILKESBARRE
NEWTON
WATER GAP
HAZELTON
POSSIBLE FUTURE AQUEDUCT TO LEHIGH & DELAWARE TRIBUTARIES
MAUCH CHUNK
BANGOR
LANSFORD
SLATINGTON
POTTSVILLE
EASTON
DELAWARE
ALLENTOWN
TOHICKON
TUNNEL
TOHICKON TO PERKIOMEN
NESHAMINY
BOOSTER CONDUIT
PERKIOMEN
READING
SCHUYLKILL
POTTSTOWN
TRENTON
AQUEDUCT TO SCHUYLKILL PLANTS
PHOENIXVILLE
NORRISTOWN
AQUEDUCT TO TORRESDALE
SHAWMONT
QUEEN LANE
BELMONT
TORRESDALE
PHILADELPHIA

FIG. 3.

the filter plants, reinforcement of the distribution systems and increased pumping capacity sufficient to secure a safe reserve to meet all emergencies.

3. In order to curtail waste, conserve supply and capacity, reduce investment and operating costs, and more equitably divide the water rates, the meter system should be extended as rapidly as feasible.

4. The draft from the Schuylkill River has practically exhausted its low season flow. This source of supply is polluted at all times and often has objectionable tastes and odors, due to trade wastes, and should be abandoned as soon as practicable. Anticipating this time the dry weather flow of the stream should be supplemented with water stored on the watershed of Perkiomen Creek. It is essential that one storage reservoir should be constructed immediately and be so located as to form the first unit of a semi-gravity supply to the part of the City now supplied directly from the Schuylkill River.

5. When it is found practicable to abandon the Schuylkill River, the Perkiomen and Tohickon watersheds should be progressively developed by the construction of storage reservoirs, from which the water should be brought to the existing Schuylkill River plants, as improved and extended.

6. When the pollution of the Delaware River at Torresdale is materially increased by the growth of commerce, industry and population in this vicinity so as to make the water at that point undesirable for use, storage reservoirs should be constructed on the Neshaminy Creek, into which water from the Delaware River above Trenton should be pumped, when found necessary, and from which the water would flow by gravity to the Torresdale filters, as improved and extended.

7. A water supply from distant sources, such as the tributaries of the Lehigh and the Upper Delaware near Water Gap, or the Susquehanna River above the Maryland State boundary line, are beyond consideration at this time by reason of their prohibitive cost (see table 8) and should not be developed until all the suitable nearby sources are fully appropriated.

8. The ground water or artesian well sources in South Philadelphia have so far been shown to be of small quantity and highly impregnated with mineral matter, making the water unsuitable for domestic or industrial purposes. However, contracts for test wells

are about to be let and final conclusions and recommendations need not be made until additional information and data have thus been obtained. Should adequate and satisfactory water-bearing strata be found in the lower part of the City, a supply could be developed as a separate unit which could be readily connected with the distribution system when and as desired.

TABLE 8

Comparative 1920 estimates of costs of projects

PROJECT*	COST OF STORAGE RESERVOIRS AND HEAD WORKS	COST OF AQUEDUCTS	COST OF FILTRATION PLANT AND CHANGES OF DISTRIBUTION SYSTEM	TOTAL COST	CONSTRUCTION COST PER MILLION GALLONS DAILY SUPPLY
1. Perkiomen.....	$ 56,073,000	$50,819,000	$28,000,000	$134,900,000	$270,000
2. Upper Lehigh..	102,635,000	176,776,000	45,000,000	324,411,000	649,000
3. Susquehanna...	19,584,000	207,703,000	28,000,000	255,287,000	511,000

* Project 1. Perkiomen, Tohickon, Neshaminy, supplemented by the Delaware River above Trenton; semi-gravity supply; recommended project.

Project 2. Tributaries of the Upper Lehigh and of the Delaware River near the Water Gap; gravity supply to reconstructed plants in the city.

Project 3. Susquehanna River above the Maryland State Line; gravity flow to existing pumping stations on the Schuylkill and to the Torresdale Filtration Plant (Elevation 35).

This recommended program in 1920 called for an expenditure of some thirty-five million dollars, at prices then prevailing, in the course of the next six or eight years and summarized in the report of the Board as follows:

First: For the construction of the first impounding reservoir on the Perkiomen Creek with necessary development of program for stored water supply $8,000,000.

Second: For improvements in and extensions to the Delaware River supply works, $6,000,000.

Third: For improvements in and extensions to the Schuylkill River supply works, $4,000,000.

Fourth: For extension of distribution mains and construction of distributing reservoir for the northeast portion of the City, $8,000,000.

Fifth: For extensions and betterments to existing distribution reservoirs and main pipe lines, $5,000,000.

Sixth: For general improvements essential for safe maintenance of plant, $4,000,000.

It will be noted that only the first item pertains to the development of a new stored water supply while the other items relate to extensions and betterments to the existing works within the City. It was estimated that during the next fifty years they will care for a population of about 3,250,000 people, which, with complete metering of all services, may allow the average consumption to be kept at 150 gallons per capita daily or an average supply of 500 million gallons daily, requiring works for limited periods capable of supplying 600 million gallons of water daily. It was estimated that the recommended project from nearby tributaries as described and supplemented by Delaware River water above Trenton would call for investments at 1920 prices as follows: Cost of storage reservoirs and head works, $56,073,000; cost of aqueducts, $50,819,000; cost of filtration plant and changes of distribution system, $28,000,000; total cost $134,900,000.

Some six million dollars have been spent during the last two or three years in revamping and enlarging the existing supply works in order to make them safe during the period required for the construction of the new supply works. This recent work is related to pumping, filtering and feeder main facilities as well as overcoming the abnormally deferred maintenance which accumulated during the war period at Philadelphia, as was generally the case with all public service enterprises.

In closing this paper, the writer desires to express his appreciation to Chief Davis and his staff for furnishing up-to-date information for record of interest to the members of this Association concerning the works of the Philadelphia Bureau of Water, the personnel of which is as follows:

CITY OF PHILADELPHIA

DEPARTMENT OF PUBLIC WORKS

FRANK H. CAVEN, *Director*

Bureau of Water

CARLETON E. DAVIS, *Chief*
Construction, John S. Ely
Mechanical Design, Harrison R. Cady
Pumping Stations, S. H. Thompson
Distribution, Daniel A. McCrudden
Filtration, Albert Tolson
Sanitary Control, Lyle L. Jenne

S. M. VAN LOAN, *Deputy Chief*
Laboratory, Dr. George E. Thomas
Accounting, Carl H. Stanger
Chief Clerk, Neill Crowley
Revenue, John J. Gaffney
Executive, Wm. W. Whitby
High Pressure, A. J. Donnelly

THE USE OF ACIDS WITH ALUM IN WATER PURIFICATION AND THE IMPORTANCE OF HYDROGEN-ION CONCENTRATION[1]

By John R. Baylis[2]

In a recent article (1) several practical applications were noted of hydrogen-ion tests to water treatment at the Montebello Filters, Baltimore Water Department. This article was based on the treatment of the Gunpowder River water after a storage varying from a few days to about 3 weeks in a 3-billion-gallon reservoir at Loch Raven. The water was fairly easily coagulated with alum most of the time, but occasionally increased quantities of coagulant were required with no material change in the mineral contents of the water. These periods were usually of short duration prior to May 1922, so no attempt was made to determine the cause.

A new dam increasing the capacity of the Loch Raven reservoir to 23 billion gallons was practically completed in the spring of 1922, but, due to delay in completing roads and bridges to take the place of those to be flooded, the water was raised in 1922 only about 12 feet above its former level. This was done in the spring shortly after vegetation had started to grow. While the area flooded was cleared of trees and underbrush, a great deal of green grass and small sprouts of trees with green leaves were covered by the water. Shortly after flooding, the amount of alum necessary for proper coagulation had to be increased. When conditions did not improve in a few weeks, experiments were started to see if any thing could be learned as to the causes, and to find, if possible, a cheaper method of treatment.

CHANGES IN THE CHARACTER OF WATER

Mineral, microscopical and bacteriological analyses of the water coming to the Montebello Filters have been made for the past few years. A careful examination of these records did not show any

[1] To be presented before the Detroit Convention, May, 1923.

[2] Principal Sanitary Chemist, Baltimore City Water-Department.

great change in any of the constituents of the water, except an increase in the microörganisms. The alkalinity and oxygen consumed values increased slightly. Color showed no great change and was possibly a little lower than usual. The free carbonic acid fluctuated, but was usually a little higher. The suspended matter decreased, but was no lower than it had been at times of low turbidity. Some of the turbidity was very finely divided, yet a great deal of it was in masses of fairly large size that appeared somewhat like finely formed coagulation. The increase in organic colloids and possibly other organic contents seemed to be the only change that might possibly have caused the great increase in the amount of alum necessary for coagulation. A second raising of the water level in the Loch Raven reservoir, beginning in December 1922, justifies the assumption that certain species of microörganisms were largely responsible for this increase in organic colloids.

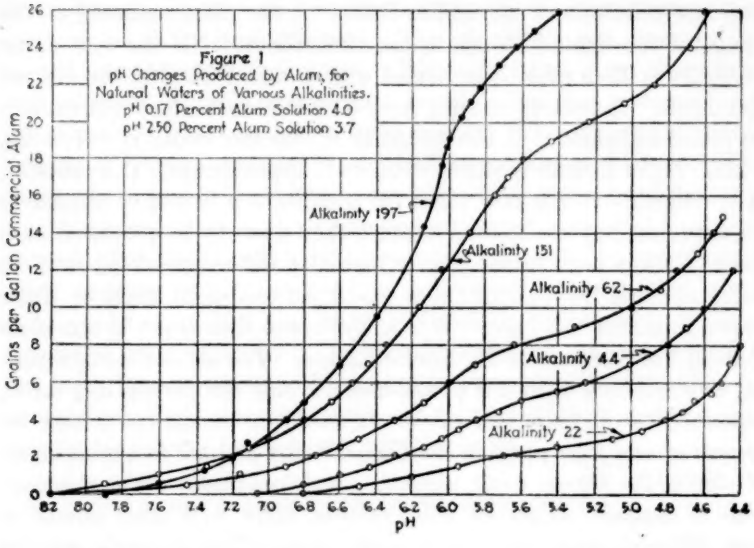
METHOD OF CONDUCTING EXPERIMENTS

To be of greatest value, experiments must be conducted according to some uniform procedure. The method preferably should be one that will duplicate plant conditions. The time of mix should produce a coagulation equal to that of the mixing basin. In our case, when one liter samples are used, it is found that fifteen minutes stirring, at 100 revolutions of the stirrer used, practically duplicates the mix in the plant when running at average rate. That is, when a liter sample of the mixing basin effluent is set by the side of a laboratory sample, in which the same amount of alum has been added, they will settle at the same rate and filter to the same degree of clarity. In the treatment of samples in the laboratory, it is necessary that every detail be followed exactly alike. Our greatest trouble has been in finding filter paper that will give uniform results. We do not expect, of course, to duplicate exactly the effluent from the filters by using paper. It has been found better to use a new filter paper for each sample, as the longer a paper is used the clearer will be the filtrate. To conserve time, the first 500 cc. of the filtrate may be used for testing the appearance of the water, and a correction made to compare it with the filter effluent. The first 500 cc. will give a turbidity and color combined about 0.2 greater than the filter effluent. Samples are compared in 75 centimeter glass tubes purchased for use with the Jackson candle turbidimeter, using a standard of known turbidity for comparison. All turbidity stand-

ards are dilutions of turbidities based on the disappearance of the image of the lighted candle in the turbidimeter. If the raw water turbidity is 25 or over, it is diluted with distilled water to the desired standards. Standards ranging from 0.2 to 2.0 turbidities will usually be found sufficient. If the turbidity of the raw water is below 25, a little Fuller's earth is added to make it approximately this amount. It is desirable to use raw water for making low turbidity standards for experimental work, even though they have to be prepared each time. It has been found that a turbidity difference of 0.2 may be detected with the 75 cm. tubes, using an opal-light glass or white paper to reflect the light. It is unfortunate that there is not some standard of comparison for filter effluents. *The old method of reporting any turbidity below 2.0 as zero does not meet our present day needs, especially for experimental work. It would be impossible to take the records of any filter plant in the United States and tell just what degree of clarity the filtered water showed. Such conditions make it impossible to compare accurately plant records, either with other plants, or with different conditions in the same plant.* The author's aim for filtered water at the Montebello Filters is a turbidity of not over 0.5 p.p.m. when determined by the above method. All the experimental work herein given is based on this same degree of clarity. The adoption of a uniform procedure for laboratory experiments has enabled us to proceed with some definite assurance of what was being done. Chemists should stop saying that they cannot tell from laboratory experiments what to expect in the plant. Such statements are merely a confession that we do not know how to duplicate plant conditions.

pH CHANGES PRODUCED BY ALUM AND ACIDS

In order to anticipate the pH changes produced by the addition of a certain amount of alum or acid, curves for different alkalinities have been plotted and are shown in figures 1 and 2. The use of color indicators for volumetric determinations usually involves the use of the hydrogen-ion concentration. That is, certain chemical reactions are supposed to be complete at certain definite concentrations of the hydrogen and hydroxyl ions of the solution. The methyl orange alkalinity is based on the amount of acid necessary to change the pH to about 4.6, the free carbonic acid on the amount of alkali necessary to change it to about 8.1, and the monocarbonate alkalinity on the amount of acid necessary to reduce the pH to



about 8.1, if it is above this amount. Consciously or unconsciously we are making use of hydrogen-ion concentrations for some of our

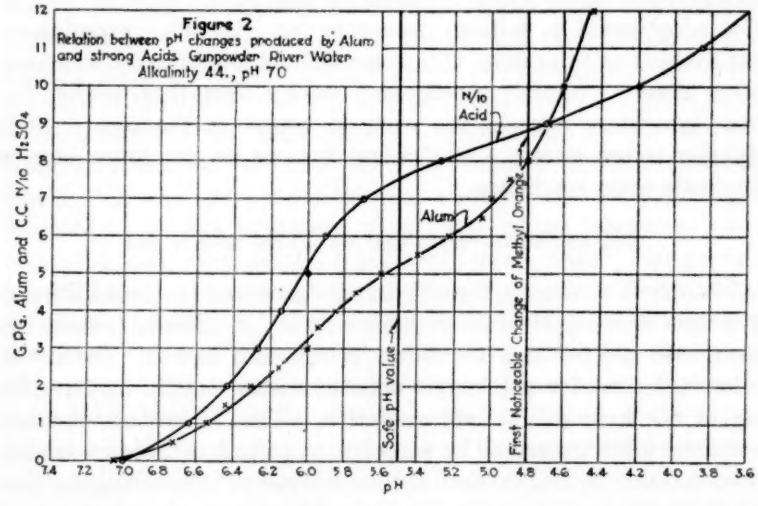


Figure 2
Relation between pH changes produced by Alum and strong Acids. Gunpowder River Water Alkalinity 44., pH 7.0
G.P.G. Alum and C.C. N/10 H2SO4
N/10 Acid
Alum
Safe pH value
First Noticeable Change of Methyl Orange
pH

chemical analyses. The unfortunate part is we are using our eyes to approximate the end point of the reactions and are not making any great effort to have the same concentration each time. One

observer may be adjusting his solutions to an approximate pH of 4.6 for alkalinity determinations and another to 4.2. The curves show what this might mean in the results obtained. There is some difference of opinion as to which is the better indicator for use in making alkalinity tests. Many prefer methyl orange, some erythrosin, and a few lacmoid. It is probable that none of these indicators gives the true end point for alkalinity. The curves indicate it might be higher than 5.0.

A few may be inclined to believe the alkalinity tests as now made give an accurate indication of the calcium and magnesium carbonates in the water. This may not be the case. Such tests do not take into consideration the buffer action of certain compounds that might be in the solution. Clark (2) has clearly shown that some compounds have considerable buffer action, even with the stronger acids. If a certain amount of strong alkali is added to distilled water and titrated with sulfuric acid, a neutral or nearly neutral salt is produced. After the reaction is complete the addition of a small amount of acid produces great changes in the hydrogen-ion concentration. So small is the amount of acid necessary to change the pH to 4.4 that it does not affect the results to an appreciable extent. If the true end point for the reaction of alum and acids with alkalinity is at pH 5.5, it is readily seen how the presence of buffer compounds may greatly affect the results, or if the reaction has no definite pH for its end point the use of color indicators are still inaccurate. So interwoven are the hydrogen-ion concentrations with chemical reactions that it seems almost incredible that its value to the water-works chemist is just beginning to be realized.

VALUE OF THE HYDROGEN-ION CONCENTRATION IN COAGULATON

It has been the author's experience that best coagulation occurs when nearly all the alkalinity has been used up, providing the amount of alum is above a certain amount varying with the turbidity. In reporting this fact to other workers it has in most instances brought forth the reply that this has been their experience. Practically no references have been found where best results have been obtained with a high alkalinity and no free carbonic acid, conditions giving a high pH value. Smith (3) states that such is the case with water containing fine colloidal clay and silicic acid. This may be the case with some waters, but experiments with the Gunpowder River water do not confirm Smith's results. Several other natural surface

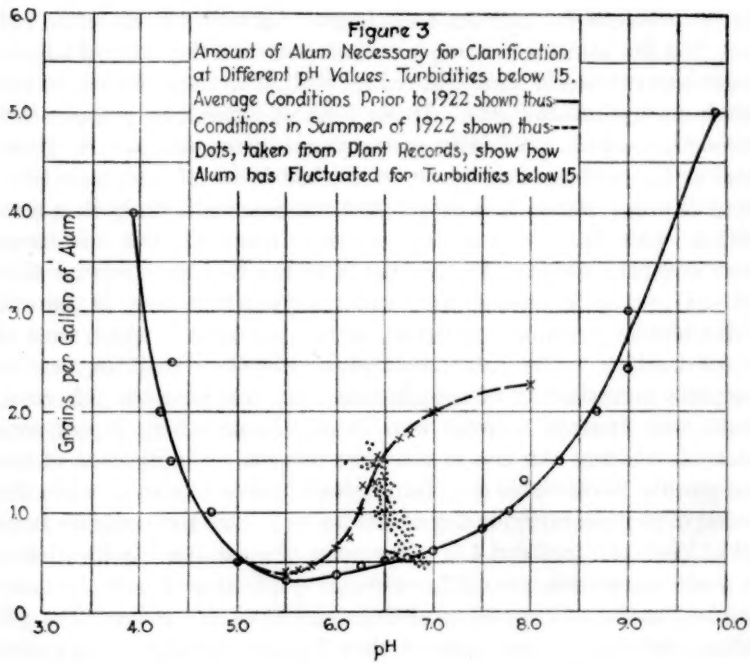
waters have been tried, and in every case best results are obtained when only a few parts per million of methyl orange alkalinity remains. In cases where there is a deficiency in alkalinity, best results were always obtained when only enough alkali was added to give an alkalinity of from 4 to 8 after the addition of the alum. This indicates there is something more or less constant for all alkalinities when nearly used up by an acid or by alum. When pH determinations are made, we find a point somewhere near 5.5 where there are indications that all the available alkalinity has gone into combination with the acids or the alum. Available alkalinity is the point beyond which free alum or free acid will exist in the solution. There may still remain a slight amount of the carbonate at pH of 5.5, and more of it might combine with greater concentrations of the acid or alum, but the substance being added will exist in the free state or some acid compound which will produce lower pH values. It makes little difference what the alkalinity or pH is in the beginning, it comes to a more or less flat place in the curve after passing 5.5 pH. That is, the addition of a small amount of acid or alum produces greater pH changes than just before this point is reached. This is shown by figures 1 and 2. Clark (4) states that the optimum point for coagulation with alum is about 5.5 pH. The author's work has tended to confirm this, but finds good precipitation may be obtained between pH of 7.0 and 5.5, when the solution is nearly free from certain undetermined organic compounds. It has been found that natural waters vary considerably with high alkalinities. In one or two instances high alkalinities and a pH slightly above 8.0 gave fairly good coagulation with an amount of alum only slightly higher than was necessary at 5.5 pH. When such conditions occurred in the experiments tried, the precipitate contained considerable calcium, indicating there might be some compound of the calcium and aluminum hydroxide being precipitated. Smith (3) states that, with a given sodium hydroxide content and the addition of graded amounts of alum, there is first dispersion, then coagulation followed by a second dispersion phase (not as stable as the first) and finally coagulation. Stein (5) refers to a cyclic occurrence of coagulation as found by some writers, but states that he was unable to find such a condition. Wolman and Hannan (6) give curves prepared by Morison showing a "zone phenomenon" in which the second point of precipitation is well on the acid side. It may be that there are three zones of coagulation, two of which might occur in some natural

waters, one at a pH slightly above 8.0, another between 7.0 and 5.5, and still another near pH of 4.0. The aluminum hydroxide zone is the one between pH 7.0 and 5.5. In the alkaline zone there must be some insoluble alkaline aluminum compound that forms. The calcium bicarbonate may have been relieved of a little of its CO_2 through some chemical or biological action taking place. It may be in such concentration that it is just ready to form a precipitate when the alum is added, or it may form a calcium aluminate which is insoluble. A little more alum may increase the CO_2 to the extent that it prevents the calcium from combining with the alumina, yet the pH is too high for forming a coagulation with the amount added. Greater quantities of alum will reduce the pH to the point where the aluminum hydroxide forms. It has been so difficult to produce this phenomenon with artificially prepared solutions that this is given more as a hypothesis than as an established fact. If such conditions occur in many waters it is hoped that some one will study it in connection with the hydrogen-ion concentration. In the acid zone some organic compounds may exist that are best precipitated at a pH near 4.0. The middle or aluminum hydroxide zone is the one with which we are most concerned, for it is the zone in which most of us are working. The data herein given will show that the nearest complete precipitation of the alumina will take place in this zone. Those who attempt to work outside of this zone may expect considerable residual alumina in the filter effluent. Clarification of the Gunpowder River water may be obtained in only one zone, when the period of sedimentation is not over 6 hours. This zone extends from pH of about 8.0 to about 4.5. The point of maximum clarification is at a pH somewhere near 5.5. Greater quantities of coagulant are required as the pH increases or decreases from this point. For pH values less than 5.0 and greater than 7.0 the increase in coagulant required for clarification becomes rapid.

Ellms (7) gives curves, prepared by Streeter, showing the effect of temperature on coagulation. Experiences with the Gunpowder River water do not confirm these results. There is every indication that temperature alone has very little effect. With the time of mix in our mixing basin, about one-half hour, or fifteen minutes stirring as described, temperature has no appreciable effect. Some of our most efficient turbidity removals have been accomplished when the water temperature was below 35°F. due possibly to the presence of less organic matter. We do not intend to convey the impression

that there is always a lower application of alum in the colder months, for we have had conditions in which the amount of alum necessary for coagulation has varied from 0.5 to 2.0 g.p.g. in a few days when the temperature was below 35°F., with no change in temperature, color, or turbidity. At such times the cause may be attributed to melting ice liberating decaying organic matter.

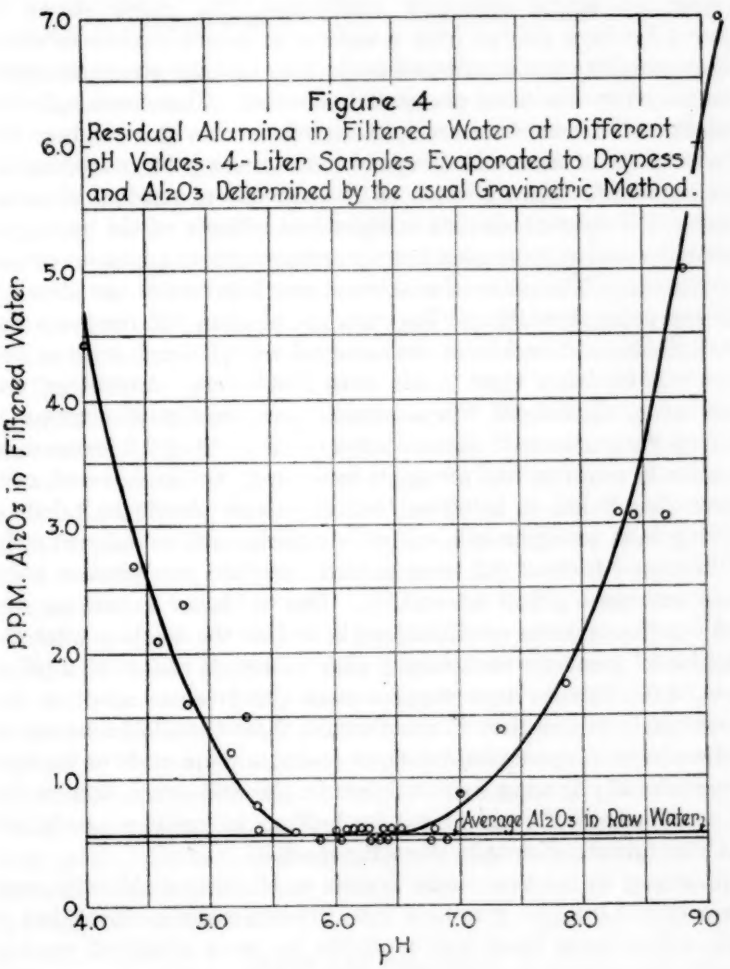
Hydrogen-ion determinations have been made a daily routine procedure since August, 1921, and have been helpful in the solution



of some of our troubles. A tentative curve somewhat as shown in figure 3 had been worked out before the enormous increase in alum requirements occurred in May, 1922. It immediately suggested the possibility of a saving in alum by adjusting the pH to a lower value. In other words, the data at that date showed a drop in the amount of alum necessary to remove a certain turbidity as the pH lowered. The curve had not been carried below pH of 6.0 on the acid side for low turbidities. The search for the turning point, or upward trend, led to the use of acids with alum.

OPTIMUM pH FOR BEST RESULTS WITH ALUM

Carefully conducted tests soon showed that the optimum point, or the point at which the least amount of alum would remove a certain turbidity, was about 5.5 pH. The curves shown in figure 3



are plotted from actual plant conditions and from laboratory experiments. The solid line represents an average of conditions prior to May, 1922. The broken line shows some of the conditions frequently

occurring since May, 1922. Plant conditions cover only a narrow range of pH. To extend the lines to extremes it is necessary to rely on laboratory experiments. So accurately may plant conditions be duplicated in the laboratory, that there is no hesitancy in using laboratory experiments to prolong the curves beyond the ranges covered by actual operating conditions. The curve shown in figure 4 has been plotted from a number of determinations in which 4-liter samples were evaporated to dryness and the aluminum oxide determined by the usual gravimetric method. This curve indicates that there is a maximum precipitation of alumina at a pH near 6.0. The quantity of alum added beyond that necessary for good coagulation apparently has no effect on the amount of residual alumina. That is, the residual alumina is dependent entirely on the hydrogen-ion concentration, providing there is sufficient alum added for proper clarification. The point of maximum precipitation of the alumina, and the point at which the least amount of alum will remove a certain turbidity may not be at the same pH value, though it is believed they will be fairly close under most conditions. Advantage was soon taken of the pH for maximum precipitation of alumina in making the gravimetric determinations. If a pH of 9.0 leaves some alumina in solution, and ammonia fumes may not be detected, even above that value, it indicates that more care should be taken in making such precipitations. Blum's experiments, as referred to by Wolman and Hannan (6), indicate that complete precipitation takes place between a pH of 6.5 and 7.5. Our procedure in making iron and aluminum oxide precipitations is to boil the solution after the addition of ammonia until faintly pink to methyl red, or to a pH of about 6.0. Results have checked more closely since adopting this procedure. At one time it was thought that it would be necessary to dissolve and reprecipitate the iron and aluminum oxide on account of occasionally getting some calcium in the first precipitation, but when adjusted to a pH of 6.0 by boiling, no calcium precipitate has been found sufficient to affect the results.

It is easy to see how, under certain conditions, a pH value even lower than 5.0 might give best turbidity and color removal, but at such a low point there will probably be more dissolved residual alumina present in the filter effluent than if the pH were nearer 6.0. When certain organic compounds are present in large amounts, and it is necessary that approximate electrical neutrality of the particles be established before coagulation takes place, it is readily seen how

the two optimum points might differ considerably. Pirnie (8) indicates this when he shows that as the alkalinity goes up on a certain water it requires more alum to produce the same results, and when the alkalinity remains the same and the color increases more alum is required.

EXPERIMENTS USING ACIDS WITH ALUM

The first acid tried was sulfuric, as it offered the greater prospect of being cheap enough for use on a large scale. So encouraging were the results, it was soon tried on a plant scale, which will be explained later. All acids tried, and especially the stronger ones, gave pH changes almost exactly alike. The ones tried which are usually purchased in the liquid form, or do not exist as solids at ordinary temperature, gave excellent results in aiding coagulation. Sulfuric, hydrochloric, nitric and acetic acids were tried. Equal amounts of N/10 solutions produced the same pH changes and aided coagulation in approximately the same ratio. Acetic acid followed closely the line of the other acids until a pH of 6.0 was reached, when it began to deviate from the stronger ones. Such acids as tartaric, oxalic and tannic did not aid coagulation. It seemed to make little difference whether the acids were mixed with the alum solution or applied to the water first. The acids offered no aid to coagulation if the original pH was restored before the addition of the alum. Carbonic acid was tried to a limited extent. It offered a slight aid to coagulation, but it is such a weak acid that it may hardly be considered, except for waters of low alkalinity and high pH. These experiments seem to justify the assumption that any strong, or fairly strong acid, which produces a neutral, or nearly neutral compound with the alkalinity, will aid alum in coagulating any water of high pH. They will aid greatly in coagulating waters which contain organic colloids that are best precipitated at a low pH, providing the minimum amount of alum does not reduce the pH beyond the optimum point. Certain acids may form compounds that make their use a detriment rather than an aid, even though they increase the hydrogen-ion concentration.

WHAT ARE COLLOIDS?

In water purification colloids are something to which we attribute most of our troubles with coagulation. The limit of size which particles must reach to be called colloids has not been definitely

established. Some are inclined to include all particles having a Brownian movement. This may be a very good dividing line for crystalloids, but we must take into consideration that particles are not supposed to have this movement at their isoelectric point. Loeb (9) says: "The colloidal state is defined by colloid chemists as that state of matter in which the ultimate units in solution are no longer isolated molecules or ions, but aggregates of molecules for which Naegeli has introduced the term micella." It has been the belief of many workers that the unit of the colloid was not the molecule or ion of the solute, and that the stoichiometrical laws of classical chemistry did not hold, the assumption being that only the surface molecules of such aggregations react with other molecules. Loeb does not believe this to be the case, especially with certain proteins, and gives proof that gelatin does combine in the stoichiometric ratio. Anderson (10) and his co-workers, in the study of adsorption by colloidal and noncolloidal soil constituents, gives one micron as the maximum size for mineral particles; and classifies all organic matter of the soil as colloidal, irrespective of whether or not it happens to exist in a state of subdivision less than one micron. Bancroft (11) adopts the very flexible definition that a phase is called colloidal when it is sufficiently finely divided, and says that: "Colloidal chemistry is the chemistry of bubbles, drops, grains, filaments, and films, because in each of these cases at least one dimension of the phase is very small." Perhaps a good definition of colloids for the water works chemist, since we do not know what they are or how to determine their amount, is "something requiring greater concentrations of the coagulant to precipitate."

COLLOIDAL CHEMISTRY AND WATER PURIFICATION

When water of low turbidity comes to the filter plant, which is no different, so far as may be detected by ordinary mineral analyses, from water that was formerly coagulated with 0.4 to 0.5 grain per gallon of alum and requires three times that amount, it is not very encouraging. When samples of this same water are allowed to stand a few days with nothing added to it, and it coagulates and settles almost perfectly clear, we begin to wonder who is tampering with it. Matter that imparts color and turbidity to water may be of very complex nature. It will vary greatly for different waters. The water may pick up nearly every conceivable kind of matter it comes in contact with from the time it leaves the clouds in raindrops until

it reaches the purification plant. The mineral or inorganic contents of water have been studied, but little is known of its organic content. Organic compounds number into the thousands, and a great many of them occur in nature. It is reasonable to believe that a great many occur in the waters of our streams. When the surface waters coming from variable soils mix with underground waters coming from springs of variable chemical contents to form our streams, it is easy to see how there may be a number of complex compounds not easily determined. The supplies for many of our cities go through impounding reservoirs with variable times of storage before reaching the filter plants. Other conditions may then arise to make the compounds still more complex in character. Microörganisms frequently grow in large numbers in these reservoirs. First there are the vegetable organisms that bring together some of the chemical constituents of the water, possibly reducing or changing some of the compounds and forming others. The vegetable organisms or compounds produced by them may be consumed by animal organisms and still other compounds produced. When the water reaches the filter plant it may be composed of such a mixture of various organic and inorganic compounds existing as solutions, crystalloids and emulsoids, that their determination is almost impossible. This complex mixture will vary greatly for different waters, or even for water from the same source. There may be such a change in the character of water within a few days time, which ordinary chemical tests may not detect, as to cause the amount of chemicals necessary for clarification to fluctuate over 100 per cent. So variable and difficult of determination are the organic contents of our surface waters that most of us have been content to do the best we can with our present knowledge and let the rest alone. If the demand for purer water keeps increasing as it has for the past 25 years, we may be forced to give more consideration to organic content. Fortunately colloidal chemistry is beginning to be studied as never before, and there is nothing that is going to be of greater aid to the colloid chemist than hydrogen-ion concentration tests.

THE EFFECT OF ORGANIC COLLOIDS ON COAGULATION

A large proportion of the organic colloids in surface waters may exist as emulsoids. Very small amounts of some, if not all, kinds of organic emulsoids have great stabilizing effects on sols. Such colloids are usually known as protective colloids. Their behavior is

greatly affected by certain electrolytes, and there is a certain hydrogen-ion concentration, varying for different emulsoids, where the protective forces are at a minimum. All evidence points to the fact that this point is well on the acid side for most organic compounds. It may be so far on the acid side in some cases that the most economical method of precipitation, when present in large amounts, will be to make the water the desired pH for best precipitation of the colloid, allow it to go through a period of sedimentation, and, after most of the coagulated matter has settled out, add the proper amount of alkali for precipitation of the alumina. This has actually been tried out in one instance with success (12). At present we are working somewhat in the dark in trying to handle organic compounds. We do not know the form or the concentration in which they exist. This is very important, for the iso-electric point has been found to vary widely. Loeb (9) states that Michaelis found the iso-electric point of several proteins varies from pH of 4.7 to 6.2. It is probable that colloidal compounds may have iso-electric points varying from pH of 4.0 to over 8.0. About the only thing we can now do is to try for the optimum condition by the hit and miss plan. There is great need for more research along this line. The curves in figure 3 show the variable conditions under which we are now working. With water practically free from certain organic compounds, the alum necessary for proper clarification may be nearly as low at pH of 7.0 as at 5.5. Plant records show that it does occasionally go below the line shown for pH values between 6.5 and 7.0. There has always been evidence of a small amount of organic colloids when the application of alum is at its lowest, and there is also evidence of considerable amount when large quantities of alum are necessary. The curve indicated by the broken line shows that the effect of the protective colloid may be largely overcome by adjusting to the proper hydrogen-ion concentration. As the protective colloids increase, the curve will keep going higher, and the optimum point will keep moving probably to the acid side.

Every indication points strongly to the fact that certain bacteria and microörganisms are great producers of organic emulsoids. Work now under way on a limited scale in our laboratory shows that the addition of a small amount of water from a concentrated growth of certain microörganisms, especially decaying animal organisms, greatly affects the amount of alum necessary for coagulation. The decay is due to bacteriological action. The iso-electric point

of these colloids is not known, but it has been found that they lose much of their protective qualities at a pH below 6.0. If alum alone is used as a coagulant, there must be enough added to overcome the stabilizing effect of the colloid before coagulation takes place. Under certain conditions it has been found that 2 grains per gallon of alum are necessary for proper coagulation at a pH of 7.0; whereas, if the pH is reduced to 6.0, 0.6 grain per gallon may be sufficient. These are conditions that have actually occurred, as may be seen from the curves in figure 3. It is noted that there is a rapid drop in the curve indicated by the broken line as the pH decreases from 6.5 to 6.0. If a certain amount of alum added to the water under our worst conditions produces a pH of 6.5, but does not coagulate, then a little greater amount is added and there is excellent coagulation, we are inclined to believe that a certain concentration of the alum is necessary to start the flocculation. A study of the curves will show that the hydrogen-ion concentration may have as much or more influence than the amount of alum over a certain minimum quantity. This is probably the cause of the sudden formation of an excellent coagulation frequently mentioned for soft colored waters.

CAUSES FOR THE DIFFERENCES IN THEORETICAL AND ACTUAL ALKALINITY REDUCTIONS

Many water works chemists have been puzzled to know why there is frequently a difference in the theoretical and actual reduction of alkalinity. When we consider the method used in making such tests, it seems that it should be the most natural thing to expect. As previously stated, many colorimetric determinations involve the use of hydrogen-ion concentrations. Clark and others have shown the great difference in the dissociation constants of acids and alkalies. In alkalinity reductions we are trying to compare a strong acid of high dissociation constant with an acid salt having a low constant, and not even taking into consideration the probability of buffer compounds. It has been found, for pH values from 8.0 to 6.0, that there is not much difference in the hydrogen-ion changes produced by strong and fairly weak acids. In applying alum or acids to water having a bicarbonate or carbonate alkalinity there is a chemical reaction liberating a weak acid (carbonic) and producing a neutral or nearly neutral salt. It is reasonable to believe that, as long as there is a complete reaction and all the alum or acid has entered into the combination, the pH changes will be alike. A point is reached, however, long before a pH of 4.8 has been obtained (the first notice-

able change in methyl red, or the disappearance of the pink color with erythrosin) where all the acid or alum does not enter into chemical combination. There are indications that this point might be a little above 5.5 pH, possibly 5.7. Our experience has been that the actual and theoretical reductions compare very closely for pH values above 6.0. The presence of certain compounds might have some effect above 6.0, but it is believed the cases are few where there is great effect. The reasons for the variation in alkalinity reductions are clearly shown by the curves in figure 2. It will be noted from these curves that it required 3.2 grains per gallon of commercial alum, that tested almost exactly 17 per cent Al_2O_3, to reduce the pH to 6.0. This should give a theoretical reduction in alkalinity of about 25 parts per million. Five cubic-centimeters of one-tenth normal acid is equivalent to 25 alkalinity, and the line of the acid curve crosses the line of 6.0 pH very close to this point. As the pH value goes below this point there is a greater deviation from the theoretical.

PROOF THAT FREE ACID OR ALUM EXISTS WHEN THE pH IS BELOW 5.5

Sulfates have little or no affect on the pH value of water. One thousand parts per million of calcium sulfate added to distilled water does not affect the ionization of the solution to any material extent. Neglecting the buffer action of certain compounds that might be present, the liberation of CO_2 controls the ionization to a pH of about 5.7. Below this value there is evidence that free acid or alum exists in the solution. The curve in figure 4 shows that there is an increase of aluminum oxide when the pH drops below 5.8.

The fact that free CO_2 may be practically all removed by boiling offers another means of determining the end point of the reaction. When enough alum or acid is added to a sample of river water to produce a pH of 6.0, and the solution is boiled vigorously for 25 minutes, the pH will change to a point above 8.0, indicating there are carbonates remaining. If enough is added to produce a pH of 5.7, the boiling will change it to about 7.0. If a pH of 5.5, the boiling will change it only slightly, possibly to 5.6 or 5.7 When pH of 5.3 or less is reached, the boiling does not increase the pH value. This definitely establishes the fact that the end point is between 5.7 and 5.3, and very likely not less than 5.5. The effect of buffer compounds have not been tried. At the time these experiments were made there was a minimum of organic colloids in the water, and it is not believed there was any great buffer action.

METHYL RED USED TO DETERMINE THE AVAILABLE ALKALINITY

The data herein given points strongly to the need of some indicator with a higher pH value than the ones commonly used for determining the available alkalinity. It has been shown that free alum or free acid may exist in a solution that is still alkaline to methyl orange or erythrosin. With waters of high alkalinity, where it is never nearly used up, this is not of much importance, but with low alkalinity waters, where the alkalinity is frequently all used up and an alkali has to be added, it is of great importance. The water-works chemist soon learns how much excess alkalinity, as is now determined, is needed to produce a fairly satisfactory filter effluent and gets along fairly well with present methods of determination. Why use a method that does not give us what we want? Many of the smaller plants cannot afford to employ chemists, and few of the larger ones have men on night duty who can make and interpret alkalinity tests. For plants without chemists or skilled operators, there is a great need for a color indicator where the mere addition of a few drops in an approximate quantity of water and mixing will tell if there is an excess alkalinity over the alum, yet will allow most of the available alkalinity to be used up. The desired indicator would be one that is colorless at pH of 6.0, and has a decided color at pH of 5.5. One may not be found that will exactly meet these requirements. Methyl red, however, is a fair substitute. There is a slight change in color before pH of 6.0 is reached, but most unskilled observers will likely want a decided change in color for their limit. pH of 5.5 is so decidedly red there can be no mistake. Skilled workers will find that they may approximate fairly closely any desired pH between 6.0 and 5.5. This indicator being used so extensively in hydrogen-ion work, makes it available in almost any form desired. The unskilled workers may purchase it in solution ready for use. The author uses an alcoholic solution in which 0.2 gram of methyl red is dissolved in 600 cc. alcohol and diluted to 1 liter. This is the same strength solution used for pH determinations. Three-tenths to 0.5 cc. is added to 100 cc. water. Unskilled workers will find changes more pronounced if 1 cc. is used in 100 cc. water. For accurate titrations the former quantities are preferable.

Methyl red has been substituted for methyl orange in our laboratory for alkalinity determinations, calling results the available alkalinity. This gives an alkalinity about 7 parts per million lower than methyl orange. Table 1 shows comparison of several indicators.

The end point is not quite so sharp for indicators where the pH is between 6.0 and 5.5 as it is for values between 5.0 and 4.0. The curve for sulfuric acid, shown in figure 2, gives the reason. There is a greater change in pH for a given amount of acid at pH near 4.5 than at near 6.0. Routine alkalinity determinations have shown, however, about the same uniformity as they did with methyl orange.

TABLE 1

Comparison of indicators for alkalinity determinations

SAMPLE	METHYL ORANGE	METHYL RED	ERYTHROSIN	LACMOID HOT	LACMOID COLD	ALIZARIN RED
1	43	36	44	43	40	37
2	198	165	199	200	190	181

EVIDENCE FROM PLANT RECORDS INDICATES THE IMPORTANCE OF THE HYDROGEN-ION CONCENTRATION TEST

The evidence of available literature and plant records seems to indicate that hydrogen-ion concentration plays a far more important part in water purification than has been generally recognized. Practically all data found seem to substantiate the correctness of the curves herein given. Stein (5), with his prepared solutions, found the best precipitation where the amount of alum added was just sufficient to react with the alkali present. There is every indication that the pH of such a solution is near 5.5. Wolman and Hannan (6), in their excellent paper on residual alumina in filter effluents, give proof that the optimum point for most complete precipitation of the alumina is at a pH near 6.0 instead of 7.0 as given in the paper. They state that Hildebrand found alumina was precipitated while the solution was still strongly acid, pH between 3.0 and 5.0, and that Blum found the precipitation of aluminum hydroxide complete before pH of 7.0 was reached when sodium hydroxide was added to an acid solution of aluminum chloride. These authors give curves plotted by Morison, showing the clarifying effect of alum for several alkalinities. The amount of alum required for maximum precipitation coincides so closely with the curves herein given, that it is safe to say that Morison's optimum pH was somewhere between 6.0 and 5.5. Morison shows considerable clarification when greatly overdosed with alum, but it may have been the latter precipitation was largely an organic emulsoid. In their own experiments, Wolman and Hannan show that the addition of acid with alum helped. With

one grain per imperial gallon and 0.8 cc. normal sulfuric acid, there is every indication that their pH was nearer 6.0 than 7.0 just after adding the chemicals.

The records of filter plants in various parts of the United States give added proof to that fact that the optimum pH is not far from 6.0. Willcomb (13), at Albany, with a low turbidity, alkalinity averaging 62, and high oxygen consumed, used an average of 1.91 grains per gallon of alum. The high oxygen consumed indicates the presence of considerable organic matter. His minimum dose for eight years, probably based on monthly averages, is 1.10 grains per gallon. There is every indication that the hydrogen-ion concentration is a very important factor in the treatment of this water. The records of a number of filter plants where alum is used, seems to justify this general statement: "With the exception of plants softening their water, there is almost invariably an amount of alum added that will allow the amount shown by the curve in figure 4 to remain in solution and have enough for clarification." In other words, if 0.4 grain per gallon is necessary to precipitate a turbidity of 15 or less and, judging from the alkalinity and free CO_2, and the indications are that the pH will be about 7.5 after the addition of 0.7 grain per gallon alum, there will almost invariably be more than this amount actually being used. There are some exceptions to this rule, where the water is softened. Most records available show, however, the application of alum above 0.7 grain per gallon.

USE OF SULFURIC ACID WITH ALUM

Our laboratory experiments showed so conclusively that the addition of certain acids to the water would aid coagulation that the use of sulfuric acid was tried out on a plant scale for the first time July 14, 1922. At this time 1.68 grain per gallon of alum was being added to remove a turbidity of 13, and to reduce the color from 15 to 6. The pH of the raw water was 7.0, which was reduced to 6.4 by the alum. Fifteen hundred pounds of 66° sulfuric acid were added to a solution containing 2400 pounds of alum, and the mixture applied to the water at a rate of 0.84 grain per gallon. This gave approximately 0.52 grain per gallon acid being applied, which, with the alum, reduced the pH to 6.2. The water coagulated just as well as it did before and filtered to the same degree of clarity. The proportion of acid to alum was carefully worked out in the laboratory before trial. To see if this was the minimum quantity for proper coagulation, the

dosage was cut down 20 per cent, resulting in unsatisfactory water. An increase of 10 per cent clearly indicated an excess for the bottom of the settling basins could be seen near their outlet, which occurs only when excess quantities of chemicals are added. Announcement of the early experiences with the use of sulfuric acid and alum has already been made (14).

Acid was tried a number of times between July and December, after which the water improved to such an extent that laboratory

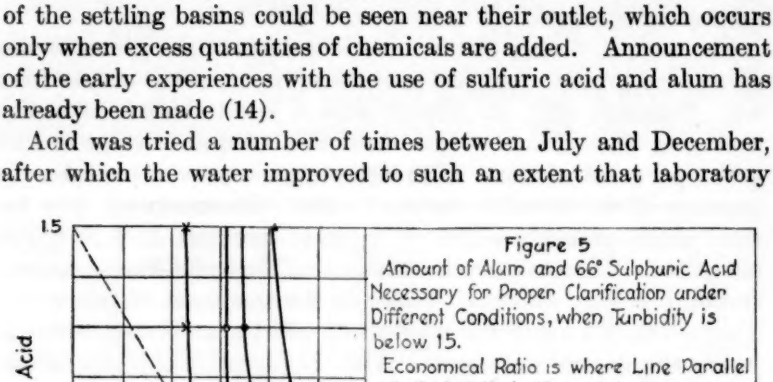


Figure 5
Amount of Alum and 66° Sulphuric Acid Necessary for Proper Clarification under Different Conditions, when Turbidity is below 15.
Economical Ratio is where Line Parallel with Cost Ratio is Tangent to Curves.
Most Points Below 0.6 G.P.G. Acid are from Actual Operating Results
Economical Area of Acid use indicated by Shaded Area

experiments indicated there would be no economy in its use. Over 2 billion gallons of water have been treated in this manner, using variable quantities of acid. On account of the acid corroding the chemical feed lines it has been applied to the alum solution through a separate control just after the alum solution passes the controller. From actual plant results and laboratory experiments the curves shown in figure 5 have been plotted, and apply only for turbidities below 15. Several curves are shown for variable conditions of the water. The point of economical use depends on the cost of acid

and alum, and the amount of alum saved. The conditions under which these trials were made indicate an economical saving when the amount of alum necessary for clarification is over 0.75 grain per gallon. The shaded area shows approximately the zone of economical use. The broken line gives the ratio of the cost of acid to that of alum, which, when the tests were made, was 0.6 times the cost of alum. The turbidity has been above 20 only a small percentage of the time since May, 1922, so curves for higher turbidities have not been accurately worked out. The indications are, that the efficiency of the acid drops off rapidly as the turbidity increases, due partly to a decrease in alkalinity at such times and a greater amount of aluminum hydroxide necessary to remove the matter in suspension. There is a certain minimum quantity of alum necessary for the coagulation of a certain turbidity, which is about 0.3 grain per gallon for a turbidity of 15 or less. As the turbidity increases the minimum amount will increase. The quantity for various turbidites should be somewhat less than the curves given by Stein (15). When the amount of alum necessary for a water of fairly low alkalinity is greater than that shown by Stein's curves, a saving might be effected by the use of sulfuric acid with the alum.

There were approximately six and a half months in the year, 1922, when it would have been economical to use acid in our treatment. This not only takes into consideration the cost of the acid, but the additional sulfates and the alkali necessary to prevent corrosion of the service pipes. There was an actual saving of over $1500 for the 2.2 billion gallons treated. Had the acid been used the entire six and a half months, the estimated saving is $12,000. An alum manufacturing plant will soon be constructed, so the proposed plan is to use the syrup alum of the most economical acidity.

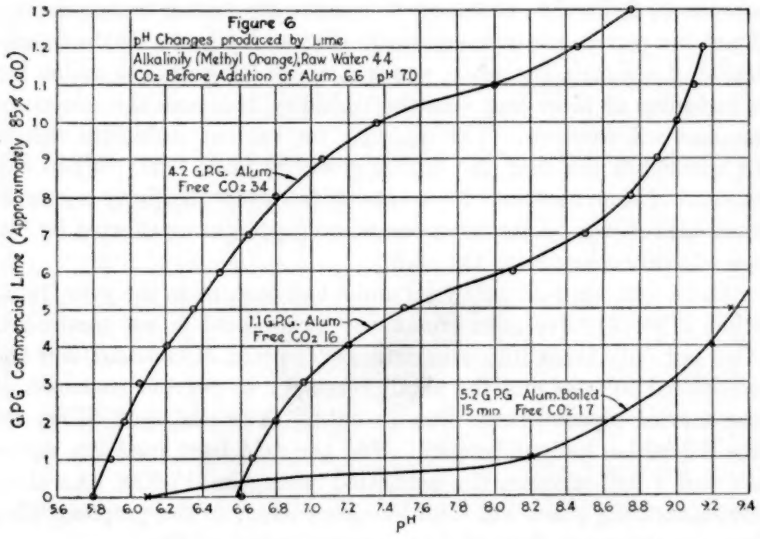
pH AND CORROSION

The author had not intended including in this paper the relation of pH to corrosion, but just as it was being completed there appeared two articles in the "Industrial and Engineering Chemistry"—one by Wilson (16) and the other by Speller and Kendall (17) in which it is stated that, for most waters, the hydrogen-ion concentration has no effect on the rate of corrosion. For fear that these articles might be misleading to those who read them, especially as the experiments were conducted on iron pipes, it seems desirable to show wherein their work is of little importance to water-works officials.

Wilson states that the fundamental reaction in the under-water corrosion of iron is, as pointed out by Whitney, divided into three distinct ranges depending upon which of these reactions is the controlling one.

$$(1) \quad Fe + 2H^{+} \longrightarrow Fe^{++} + 2H.$$
$$(2) \quad 2H + \tfrac{1}{2}O_2 \longrightarrow H_2O.$$
$$(3) \quad 2H \longrightarrow H_2 \text{ (Gas)}.$$

In alkaline solutions with a pH above 11 or 11.5, Reaction (1) is slowest of the series and therefore determines the rate of corrosion in this range. As a result, corrosion is always comparatively slow, and the hydrogen-ion con-



centration and the temperature are the two most important variables. In the range from a pH of about 11 to one about 4, which includes practically all natural waters, Reaction (2) is slower than Reaction (1), but faster than the parallel Reaction (3), and hence it determines the rate of corrosion. It further appears that the slowest factor in this reaction is the rate of diffiusion of the dissolved oxygen through the stationary film of water on the iron surface, and hence oxygen concentration and velocity of flow are the two most important variables, temperature alone being important, though less so than in the other ranges, while the effect of the hydrogen-ion concentration and the nature of the metal are negligible. In acid solutions, below pH of 4, Reaction (3) becomes more rapid than Reaction (2), and determines the rate of corrosion.

Speller and Kendall give figures and curves to prove that the corrosion is directly proportional to the dissolved oxygen concentration. Most of their experiments were on $\frac{1}{4}$, $\frac{1}{2}$ and $\frac{3}{4}$ inch "National" standard pipe, using Pittsburgh tap water. The corrosion was determined at various temperatures. While the pH of the Pittsburgh water is not given, there is indication from the other analyses that it is below 6.5, which should give a fairly corrosive water. Their conclusion is that the pH of most natural waters does not effect corrosion.

Only slight mention that protective coatings might be formed is found in both articles, and no mention that the pH is the governing factor in the formation of these coatings. It is unfortunate that two such excellent papers should ignore almost entirely the most important factor in pipe protection. The life of iron pipes depends almost entirely on the protective coating, whether it be one artificially applied, such as galvanizing or painting, or one formed by the water. If only a small per cent of the total corrosive properties of most surface waters were used up in corroding iron pipe, the life of such pipe would be extremely short, and the water at the faucets very much discolored by the iron. Water should, and does in some of our supplies, reach the consumer with considerably less than 5 per cent of the corrosive properties used up, an amount that it is impossible to measure with any degree of accuracy. The author does not concede that the pH is not the controlling factor after a coating of iron rust has formed. There is one sentence, however, in the article by Wilson that every chemist should constantly bear in mind in making experiments. "It is probably not out of place to emphasize . . . . the fallacy of making tests in one region, and applying them in another, as has so frequently been done in the past."

Perhaps a parable will best illustrate the importance of the protective coating. We will assume that there is a field of wheat representing iron pipes, and a herd of cattle representing forces trying to consume and destroy the wheat. The data brought forth in these articles would apply to the magnitude of the herd of cattle and their capacity to consume and destroy the wheat. From this the farmer might figure how fast the wheat will be destroyed if the cattle are allowed free access to the field. It might be very valuable information for the farmer, but it does not tell him how to protect his wheat, which might be by far the most important consideration. The pH figures (which vary in the same direction as the hydroxyl-ions and in this case will represent such ions) represent men. That is, pH 1 equals one man and pH 10 equals 10 men. The mineral contents of

the water will represent material over which the cattle will have to pass to get to the wheat field, and also material available for the pH men to build a protection around the wheat field. Some of the material will offer no obstruction to the cattle, but part of it might, if in sufficient quantity. The calcium carbonate contents of the water will represent stones requiring 8½ pH men to place in a fence, and the sodium carbonate contents will represent some soft substance that is not stable. If only one pH man is guarding the field, about all he can do will be to prevent a few cattle getting in. If 4 pH men are guarding it they may keep a larger number of cattle out and retard the rate of consumption of the wheat, but cannot build a protection. The rate of destruction of wheat between 1 pH and 4 pH will vary as the number of men, the number of cattle, and the amount a cow may consume. If 8½ pH men are available they not only can guard the field better than 4 pH men, but can gradually move some of the calcium stones to build a protection around it. Given sufficient time they will build a protection almost impermeable to the cattle if sufficient calcium stones are available. If there are very few calcium stones and considerable sodium present, they may make the field a little less accessible, but can form no permanent protection. If the pH men are increased to 12 or 13, they not only can build a protection much more rapidly when material is available, but can keep a larger number of the cattle out. A point might be reached where there would be enough men to keep all cattle out without a protection. To make the story complete we will assume that there are acid men (representing the acidity of the water or hydrogen-ions) trying to destroy or remove the calcium protective stones, and that it will require from 7½ to 8 pH men to resist this force. When the 8½ to 9 pH men have completed the calcium fence to where it cannot be passed over by any of the cattle, destruction of the wheat by the cattle will cease as long as the fence is maintained. The force of pH men may then be reduced to where there is just enough left to overbalance any force tending to destroy the fence, and there need not be a large supply of calcium stones available all the time. The oxygen contents of the water bears the same relation to corrosion as the cattle do to the wheat. If unprotected, the rate of destruction is in the ratio of the number of cattle, or the dissolved oxygen. It is far cheaper to build a fence around the field than to try ro raise wheat near a herd of cattle. To have any wheat for the market the quantity must be in excess of the consuming powers of the cattle.

It is necessary to have some substance like calcium carbonate that is nearly insoluble to form a protective coating on the pipes. It requires a pH of from 8 to 9, depending on the concentration of the calcium bicarbonate, to cause a deposit to form. From the alkalinity and carbonic acid tests we may be able to tell when the deposit will form, but is this not a hydrogen-ion determination? We are compelled to use hydrogen-ions whether we wish to call it that or something else. Hydrogen-ions alone do not tell the whole story, neither does alkalinity or any other single test. In most cases where iron and lime are used as a coagulant, and the water receives no additional treatment, there is practically no corrosion of the pipes. This is due to the fact that iron usually requires a pH somewhere above 8.0 for best results. We might be better off if alum required this same high figure.

Water-works officials need not be unduly disturbed over the conclusions given in these two papers. They give valuable data, and the authors deserve much credit for their work, but they cover only one phase of the life of iron pipe. This phase very likely depends on the dissolved oxygen present, but the fact that it may be reduced to where it is of minor importance by protective coatings, makes it of little consequence. When water is delivered to the mains with a pH of about 9.0, giving practically no complaints from consumers of "red water" and, when changed to a pH of about 6.5, results in numerous complaints, there is every indication that the pH has a great deal to do with it. If the water is again treated with lime to produce a pH of about 8.0 and complaints of "red water" practically cease, we feel convinced that pH is the controlling factor. This is what has actually happened in the Baltimore supply, since the author has been connected with the department.

One great trouble with most water purification plants is that they are designed to apply both chemicals somewhere near the beginning of the purification process. This is probably the proper thing to do when iron and lime are used, but with alum the alkali should be applied after filtration, except an amount which might be needed to produce the optimum pH for precipitation of the alum. Few plants are constructed so that the alkali may be applied uniformly after filtration. This is unfortunate, for it will mean that many plants will continue delivering corrosive water to the mains. It might be cheaper in many instances to spend twenty or thirty thousand dollars for remodeling a purification plant than to have a hundred thousand dollars worth of pipes destroyed within a few years.

The total soap hardness of the Baltimore water before treatment is about 40 parts per million. Increasing the pH to about 8.0 with lime after filtration increases the hardness from 8 to 15 parts per million. The consumers are much more satisfied with this small increase in hardness than they were when lime was not applied. The increase in the iron contents of the water in passing through the distribution system is now about 0.05 parts per million, which added to the iron remaining after filtration, gives a total iron content of about 0.15. The author has been asked several times why he used pH, instead of making the water slightly pink to phenolphthalein, to control corrosion. Some chemists apparently have not discovered that they are already making a partial use of hydrogen-ion concentrations in their work without taking advantage of a more accurate and intelligent procedure.

A PLEA FOR GREATER RECOGNITION OF THE IMPORTANCE OF CHEMISTRY AND BIOLOGY IN WATER PURIFICATION

It was realized in the preparation of this paper that one important part would be missing, that is the theoretical reasons for the assumptions herein given. A few days before the final copy was made, an article by Theriault and Clark (18) appeared in "Public Health Reports," which largely supplied this deficiency. Their data, both theoretical and experimental, coincide closely with results found in practice. Every water-works chemist using alum for a coagulant is urged to obtain a copy of this paper. It is unfortunate we did not have it years ago. So great is the necessity for more research work in water purification, that we offer a plea for such a change in conditions as may be necessary to attract more of the leaders of the chemical and biological profession to this field.

When we look over the history of chemical treatment of water, and of rapid sand filtration, we marvel at the progress in the past twenty years. To have been connected with the development of this art is an honor of which any one should feel proud. If any criticism may be offered it is that practically all efforts have been devoted to the development of the art and little to the science. This is in accordance with the history of many of our accomplishments. First, the demand, second, the art, and last, the science. It is usually only when the art fails to produce desired results that we give serious consideration to the science. In some branches of industry the art was developed hundreds of years ahead of the science.

When we charge that the art of water purification is much ahead of the science, it does not reflect upon the glory of many of our leaders who have done so much in the past. They have worked under the assumption that chemistry and biology followed certain well defined laws, which had been worked out years ago. When troubles have arisen they have, in most instances, tried to solve them by hydraulics and engineering instead of by chemistry and biology.

Progress, as a rule, is slower in any line of industry involving two or more distinct branches of science. The leaders of any two professions, requiring the same efforts and training, expect the same consideration. Members of one profession need not expect those of another of equal standing to work under them for considerably less pay. They will get men equal to those of their own profession who are receiving such salaries. The engineering profession largely dominates the design and operation of purification plants. Perhaps, they are justly entitled to such domination. If water purification engineers desire to produce the best results, they must seek the advice of the leaders of the chemical and biological professions. They should not take a few fundamental facts and think they have all that is needed from these professions, nor should they expect the leaders to establish research laboratories and impart their knowledge to them for nothing. We fear that in too many instances the engineer's idea of a proper organization for a water purification plant is a $3000 engineer for superintendent and a $1500 man for chemist. In some instances the engineer merely wants someone to tell him a few of the chemical properties of the water, and its bacterial contents, leaving the interpretation of results to himself. The author is glad to state that these are not the conditions under which he works.

We have reached the dawn of a new era in water purification. Past conceptions in some instances will give way to newer ideas. Chemical and biological problems will be solved by men who have trained themselves in that line of work. Fortunately the universities are now offering courses in sanitary engineering, that are giving as much time to chemistry and biology as to engineering. We appeal to the engineers to share some of their glory with the chemist and the biologist. Without such coöperation progress will be slow and expensive.

The author wishes to acknowledge his indebtedness to Mr. Abel Wolman for several valuable suggestions in the preparation of the subject matter and form of this manuscript.

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STEEL PIPE FOR LARGE WATER MAINS[1]

By Theodore A. Leisen[2]

In submitting a paper on steel pipe at this stage, the writer is acting contrary to the dictates of his best judgment, for the time and opportunity available for collecting data, or making adequate research since the request for this paper was received, have been too limited to permit the compilation of pertinent facts and figures, the absence of which places such a paper in the category of a mere progress report, devoid of much of the information which properly it should embrace, and inconclusive in its ultimate analysis. With full appreciation of its limitations in the field of research and its relatively synoptic proportions in the epitome of presented facts, this apologetic prologue is offered in extenuation for the inadequate handling of a subject, which, by reason of its importance, demands much fuller consideration. As a further evidence of contrition, the writer hopes that an opportunity may be afforded a year hence to present this subject in unabridged form with all attainable data collected and classified in one concrete report.

It is not the purpose of this paper to inaugurate a controversial discussion between the steel and the cast iron pipe interests or between the champions or advocates of either class, although it is practically impossible to approach the subject without some reference to and comparisons between the two classes of pipe. In the endeavor to portray the merits of the modern types of steel pipe under certain conditions, it should not be construed that cast iron pipe is being condemned even by implication. The intent is rather to offer in a cursory way some facts relative to steel mains laid in the past and their behavior under the stress of actual service conditions, to serve as a guiding note to those who have in contemplation the adoption of such pipe for water supply purposes.

[1] Presented before the Philadelphia Convention, May 19, 1922.

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SELECTION

In giving consideration to the selection of large water supply mains of considerable length, the primary factors to be determined by the engineer are the cost of material and installation, the probable life of the pipe, and its reliability to withstand safely all contingencies which local conditions may indicate as probable, or even remotely possible factors tending to rupture or otherwise destroy the pipe, either through excessive internal pressure or from external causes. In reaching a conclusion, the probable life of the pipe—in itself a most important qualification—should not be the only factor to receive consideration.

COST

In all projects of large dimensions cost becomes an item of prime importance and in selecting the class of material for large water mains, cost must be considered. The manufactured cost of steel pipe is less than that of cast iron, and freight rates further increase the disparity, depending on the distance between the source of manufacture and final destination. In certain localities, therefore, the difference in cost reaches a point where it must be reckoned with, and this applies with particular emphasis to pipe thirty-six inches in diameter and larger, and with added force to the larger sizes. The cost of local hauling, handling and laying also should be less for steel pipe when handled in an efficient manner. The total difference in cost considered as a sinking fund, and computed at compound interest at current rates for a period of years equal to the assumed life of the steel pipe, should provide a basis to determine the relative value of the pipe from the financial viewpoint.

LIFE OF STEEL PIPE

But what is the assumed life of steel pipe? The use of steel in the manufacture of water mains being a development of comparatively recent years, there are no data extant to determine definitely the actual *average* life of such pipe under ordinary conditions of service, but the experience of the last twenty or thirty years has demonstrated that it may be depended on for a much longer period than was credited to it by most engineers in the past. An approximate idea of the probable useful life of steel pipe may be obtained only by accepting as a basis the established facts regarding existing

lines of riveted pipe that have been in continuous service for periods of fifteen to thirty years, and by computing the total life by proportioning the percentage of deterioration, if any, evidenced during its past period of service, to the total percentage of deterioration which would make the pipe unfit for further service.

Following this method of procedure and using rational judgment in its application, it may be shown that in some instances steel pipe may attain a useful life of one hundred years. The principle involved in the suggested method would in reality be on the side of conservatism, as apparently the first rust scale forms more rapidly than successive ones, and if the first ten years showed a given loss by corrosion, it is doubtful whether the second decade would show a proportional loss.

As a basis for the application of this method for computing the assumed useful life of the steel plate, a few concrete examples, taken from records at hand, are submitted:

1. A 50-inch diameter riveted pipe was installed at Pittsburgh, Pa. fifty-one years ago, and is still in service, but the deterioration suffered could not be ascertained.

2. A riveted steel main, 50 inches diameter, laid in Allegheny, Pa., twenty-seven years ago, is still in service, and an examination of a section of plate cut therefrom shows no appreciable deterioration.

3. A section of 62-inch diameter riveted steel pipe recently removed from a connection to the settling basin of Detroit Water Works, and which has been in service in that position for forty-five years, but which apparently had been used for some other purpose prior to its installation and therefore may be several years older. This pipe was made of $\frac{3}{8}$-inch plate. The exterior surface of the plate was in excellent condition, the original paint still remaining in places, but the interior showed some corrosion and pitting; the deepest pits being about $\frac{1}{32}$-inch, or less than ten percent of the thickness of the plate. Assuming that the plate could be pitted to 50 percent of its thickness before its efficiency would be destroyed—and this is a conservative assumption—then this pipe would have a useful life of five times forty-five or over two hundred years.

4. Several miles of 48-inch diameter steel pipe laid in New Jersey, near Newark, which have been in service for twenty-seven years show little or no indication of deterioration, although portions of these lines are subject to occasional contact with salt water.

5. About four miles of 43-inch and 48-inch "Lock Bar" steel

mains laid in Wilmington, Delaware, seventeen years ago, apparently are in as good condition as when laid, except at certain points where they were attacked by electrolysis, and where cast iron pipe in the same locality suffered to a similar extent. Numerous other cases might be noted, but those mentioned are sufficient for purposes of illustration.

The examples cited are all favorable ones and may depict results above the average, so it must not be inferred that all steel pipe under all conditions will be equally resistant to corrosive agencies. Certain waters may have a deleterious effect on the interior, and acid soils in which corrosive influences exist will attack the exterior, and in considering the probable life of steel pipe in contemplated installations a thorough study of these conditions should be made before a decision is reached.

STRENGTH OF STEEL PIPE

The number of breaks recorded in large cast iron mains with the disastrous attendant results, induced some engineers, whose minds were open to conviction and who were willing to depart from established precedent, to look for some type of pipe that would preclude the possibility of a continued recurrence of this tendency towards sudden and unexpected rupture. Naturally wrought iron and steel plate with their higher tensile strength suggested themselves as logical substitutes. Not merely the greater tensile strength, but also the great ductility, higher elastic limit, and generally increased reliability in their predeterminable ability to resist rupture within fixed and definite limits, were all potent factors in commending these materials. Because of the trend of manufacturing technique, steel plate has become the metal commercially available.

The superiority of steel plate over cast iron in the matter of strength and freedom from rupture is not a debatable question and will be accepted without discussion, but, negatively, two elements of doubt enter into the general subject, the corrosive-resistant properties of cast iron in comparison with wrought iron or steel and the relative values of wrought iron and of steel along the same line. That cast iron is superior to either wrought iron or steel in this particular also is an undebatable question, the value of cast iron on this point being too well established to admit of any doubt, and the greater thickness of the shell will permit of considerable pitting or scaling before its strength is materially impaired. Between wrought

iron and steel, however the relative merits are open to controversy, although there is no conclusive evidence to prove either side of the contention. It may be assumed, therefore, that these materials are not radically dissimilar in anti-corrosive properties. To the best of the writer's knowledge there are no records of any water mains having burst because of corrosion, so that this affects its durability rather than its strength and has been discussed previously under the head of life of steel pipe.

In computing the thickness of plates for steel pipe it would seem desirable to keep the stresses in the plate below 10,000 pounds per square inch. This may appear to be an unnecessarily high factor of safety, but the additional thickness of metal will not impose a prohibitive increase in the cost. The extra thickness allows for considerable pitting without serious effects, and even under uniformly progressive corrosion the useful life of the pipe would be prolonged beyond the term which the theoretically correct thickness would permit. If an empirical rule may be advanced, it would be to employ no plate less than $\frac{1}{4}$ inch thick for any sized pipe, and not less than $\frac{3}{8}$ inch thick for mains 42 inches diameter and larger, regardless of how low the water pressure may be.

TYPES OF STEEL PIPE

Large steel pipe today is being fabricated in three distinct types, riveted, lock-bar and hammer-welded. The riveted pipe is the oldest form, being made up usually of four plates to a thirty foot section, rolled to shape with single riveted circumferential seams about every seven and one-half feet and one double riveted longitudinal seam to each plate alternating on opposite sides, all seams being caulked. It is usually shipped in 30-foot lengths and designed for riveted field joints. Lock-bar pipe is made of two plates 30 feet long and of a width approximately equal to one-half the circumference of the pipe, evenly sheared and upset on the two side edges, rolled to shape, and the two semi-cylindrical plates joined together by continuous H-shaped lock-bars 30 feet long, one on each side of the pipe, the side of the grooved section of the lock-bar being forced down hydraulically over the upset edges of the plates. This pipe is made in standard lengths of 30 feet except when otherwise required. Usually it is made for riveted field joints, although certain other types of joints are applicable. Hammer-welded pipe, the latest development, is made of two plates usually either 20 or 30

feet long, and of a width slightly greater than half the circumference of the pipe to allow for the weld lap. The two plates are rolled to proper shape, fastened together with temporary clamps, and each lapped joint heated with a gas flame to proper temperature, and hammer-welded with an extension cantilevered mandrill and power hammer, the heating and welding being done successively in sections about 18 inches long. Only one side seam is welded at a time, the welding being done on the up-turned side of the pipe. After welding both seams, the pipe is heated and re-rolled to remove scale and for final shaping. Mills fabricating hammer-welded pipe are being equipped to roll and weld thirty foot lengths. Shipments of 40-foot sections may be made by circumferentially welding two 20-foot sections together. Welded pipe should be made in sections of absolutely uniform length, but such is not the present practice. Welded pipe may be supplied for riveted field joints or with bell and spigot joints for lead caulking.

In the scale of comparative values the riveted pipe stands the lowest of the three types, both on account of its lower carrying capacity and the weakness of the riveted longitudinal joint. The greatly increased number of rivet heads and lap joints form obstructions which impede the smooth flow of water, reducing the velocity, and in the same ratio the capacity, while the riveted longitudinal seams develop only about eighty percent of the strength of the plate. Both lock-bar and hammer welded pipe present smooth, unbroken surfaces for the full length of the sections which under recent methods of fabrication need not be less than 30 feet in length, and, depending somewhat on the type of joint, little or no impediment to the normal flow of water is apparent. The lock-bar joint for lateral seams develops the full strength of the plate, and the welded joint likewise is said to achieve the same result, although there is some question as to whether the tensile strength of the section of plate adjacent to the weld is not reduced in the process. In any general comparison it would seem proper to provide fixed differentials in favor of lock-bar and welded pipe for both capacity and strength.

COATING

The coating of steel pipe is one of the very important factors in preserving the plate, and the first requisite of a good coating is its ability to adhere to the steel. Durability and flexibility are both desirable properties, but lose their value if the coating has a tendency

to blister or peel off or separate itself in the slightest degree from the plate. It is questionable whether the best coating has yet been found, although some excellent materials and methods are now in use. Chemists are at work in an effort to improve these materials or to discover a preferable substitute. A coating with high adhesive qualities and one that will insulate in some degree against stray electric currents would appear to be the desirable end.

In addition to the regular shop coating, material for field coating must be provided to cover abrasions resulting from shipping and handling. This presents a different problem, as the field painting cannot be performed under the advantageous conditions existing at the shop. Too much stress cannot be laid on the importance of using every reasonable precaution in handling and laying the pipe to avoid damaging the shop coating, of re-coating in the most thorough manner all sections of the surface which have been damaged and of covering all field riveting and caulked edges.

CONCLUSION

It must be realized that this is but a superficial presentation of the whole subject. It is submitted in order to bring out discussion both adverse and favorable in the hope that the ultimate result will be an accumulation of facts and theories which, when combined in concrete form, will furnish data of value to all water works interests.

UNDERGROUND LEAKAGE AND ITS RELATION TO MAINS AND SERVICES[1]

By Thomas F. Wolfe[2]

One of the most convenient ways of reporting underground leakage in flow lines and distribution systems is in gallons per day per mile of pipe or gallons per day per foot of joint. Either of these figures is a fair indication of the efficiency of the transmission system only when there are no service connections to it. As soon as other means for water to escape are introduced, it is absolutely unfair to report or consider leakage as a function of the length of the main. Unfortunately, a better system does not readily offer itself because of the way leakage figures are determined. It is also unfortunate that the method of arriving at the amount of water lost in transmission involves so much guess work, because lack of accuracy is responsible to a great extent for the fact that large water losses are so easily condoned. In determining the amount of water escaping underground, the usual way is to account for all that is fairly measurable and then to ascribe the remainder to leaks. This involves considerable estimating and the net result, as far as unaccounted for water is concerned, is nothing more than an estimate. On account of its unreliability, it is not taken as seriously as it should be. In fact, many water works men have come to look upon a large underground loss as a legitimate expense and, consequently, disregard it. In reality, there is small excuse for this condition because pipe may be laid so that it will be almost absolutely tight and, if proper material and workmanship are used, there is no reason why the pipe should not remain tight indefinitely.

In examining water works statistics, it is not at all unusual to find many systems reporting losses of from 20 to 50 per cent of the water pumped. If this were true of those cities and towns where water is still sold on a flat rate basis, it might be ascribed to waste within the premises. As a matter of fact, this is not the case and many towns

[1] Presented before the Philadelphia Convention, May 16, 1922.

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that are 100 per cent metered are unable to account for the entire pumpage without charging off a considerable percentage to underground losses. Possibly, all leaks cannot be eliminated, but more serious consideration of the reason for leaks will at least greatly reduce the percentage of unaccounted for water.

The thought that services are responsible for a large part of the water loss is not at all new, but it may be worth while to consider some accurate data indicating the truth of this statement. Tests of parts of the underground system in Chicago made either by the writer or under his direction, give some interesting data in this connection. A test was made on the Stock Yards in Chicago, where it was comparatively simple to measure the total flow in the district under test and where practically the entire consumption was metered. The Stock Yards occupy an area of about 1 mile square, the eastern half of which is occupied mostly by cattle pens and is not supplied with city water. The remainder of the Yards is closely built up with packing plants, where great quantities of water are used. Every service in this entire district, except those supplying fire engine houses and public drinking fountains, is metered and with the exception of a few ¾-inch services supplying elevated stations and isolated buildings, are of cast iron. In other words, this system might be considered free from service leakage, as the services themselves are constructed in exactly the same manner as the mains.

In conducting this survey, the mains carrying water into the Yards were shut down with the exception of two 24-inch mains, one carrying water from the Twenty-Second Street pumping station, the other from the Sixty-Eighth Street pumping station. This created a number of dead ends and in order to avoid any danger from a limited supply in case of fire, a man equipped with a valve key was stationed at one of the Fire Engine Houses within the limits of the Yards, with instructions to operate such valves as would increase the supply in case of fire. It so happened that during the period of the test, no fires originated in this territory. Consequently, the valve arrangement was not disturbed. Pitometer taps were installed on each of these two supply mains and traverses were carefully run. All meters were read at the beginning of the test, the reading was repeated at the end of the run and the daily rate of consumption was established from these readings. According to the pitometer, the rate of consumption varied from a minimum of 6,960,000 gallons per day to a maximum of 24,100,000 gallons per day and the pressure from

twenty-four pounds to thirty-seven pounds. The daily rate of consumption was plotted on a curve and the average daily rate was computed to be 14,562,000 gallons. The rate as shown by the meters was 13,782,000 gallons per day. This leaves 780,000 gallons per day to cover the following items:

Service to three engine houses, 21,600 gallons per day
Two continuous drinking fountains, 14,400 gallons per day
Hydrant Leakage, 35,100 gallons per day (Based on average hydrant leakage all over the city)
Water used from fire hydrants for street washing, 10,000 gallons per day
Meter slippage, estimated at 2½ per cent, 366,000 gallons per day,

which leaves 2.28 per cent of the total flow into the district unaccounted for. This figure indicates that, with service pipe leakage eliminated, the amount of unaccounted for water is negligible.

We will now consider tests made on various streets in districts where conditions are different, that is, instead of an all cast iron system, we have a cast iron main and service pipes of other material. For the past five years, it has been the practice in Chicago to test each street for leaks prior to laying pavements. Not only are the tests made, but the leaks are located and over 92 per cent of the water escaping in these streets has been stopped. This intensive leakage survey naturally brought to light the exact nature of the leaks. The streets tested may be considered average cases, because in some, the mains and services were just laid, while in others, the pavements to be laid were replacing other pavements that had been worn out and the mains in these streets were from twenth-five to seventy years old. The tests are conducted in the following manner:

The section of main to be tested is shut down and all services shut off at the roundway at the curb. A 1-inch meter, (or where the section is large, a 2-inch meter), is then by-passed around one of the closed valves through a 2-inch hose connected to 1-inch corporation ferrules installed on either side of the closed valve. If any leakage is indicated, an aquaphone is applied to a shut-off rod on each roundway and as a rule, if the leak is any place on that particular service or on the main near the service, it may be easily heard. With experience, a man can tell about where a leak is by the relative loudness of the sound on adjacent services. If there are no services on the main or, for some reason, the location of the leak cannot be determined as described above, a 1-inch earth auger is used to bore a hole down to the main itself. An aquaphone applied to

rods in these holes will pin the leak down to a very small space. This method obviates digging numerous test holes in order to determine leak locations and has been used successfully in paved streets, where the only opening in the pavement is that caused by driving a bull point through it. If the leakage is particularly difficult to locate, the main is cut in two and patent plugs similar to those used by plumbers in testing house drainage systems are installed in place of the pipe cut out. The water getting away in the section between the meter and the plug is then measured and, in this way, the section in which the leakage occurs is located. In cases where the valves are not located in such a way as to make it possible to isolate the section desired, the main is cut at the limits of the section to be paved and these plugs used.

During the year 1921, 78½ miles of streets have been tested in this way and 1,091,000 gallons per day of leakage have been measured; 1,070,990 gallons per day or 99 per cent of the total leakage has been stopped. Of this amount, 92,000 gallons per day was stopped by abandoning a main. This main lay under street car tracks in a downtown street and, because of dense traffic, it was cheaper to lay a new main. The remainder of the leakage was divided as follows:

	gallons per day
Service pipes	648,878
Joints	65,161
Hydrants and valves	259,751

The hydrant and valve leakage is excessive because in spite of ordinances to the contrary, hydrants are subjected to considerable abuse by being used by building, paving and sidewalk contractors and others for construction purposes. The service pipe leakage of 648,878 gallons per day or 60 per cent of the total underground loss was found to exist mostly in wiped joints. This figure on service pipe leakage is somewhat lower than it should be because of the fact that, prior to making these tests, it is customary to cut off all wrought service pipes and replace them with lead service pipes. It is impossible to estimate how much additional leakage would have been measured had these rusted out wrought pipes been included in the survey, but, as most of these pipes are in bad condition, it is reasonable to suppose that this figure would be materially increased. It should also be borne in mind that this includes only that part of the service

pipe leakage between the main and the roundway and that leakage in these pipes between the roundway and the premises is not included. In Chicago, wrought pipe is often used by building contractors between the roundway and the house in the effort to keep first cost down. Experience has shown that these pipes have a very short life and are responsible for a great part of the underground losses.

From these figures, it may be seen that less than 7 per cent of the leakage is charged in any way to the main and none of this is due to leaks in the pipe itself. If the total leakage in these streets were reported in gallons per day per mile of pipe, it would be 14,000, whereas the actual leakage in the main itself was 830 gallons per day per mile of pipe or less than is often specified for new pipe. For the entire period of five years, 350 miles of pipe have been tested, 7,038,000 gallons per day of leakage have been measured and 6,510,000 gallons per day or 93 per cent of the leakage has been eliminated.

The oldest main tested since this system was adopted was a 12-inch cast iron main laid in State Street in 1852. This main is part of the first main laid in Chicago after the use of bored logs was discontinued. The section of this main tested was 1500 feet long and was found to be absolutely tight. There were only three services off of this main and they were all cast iron. A 6-inch tap, for the purpose of connecting a hydrant to this pipe, made it possible to inspect the interior as well as the exterior of the pipe and there was little evidence of corrosion. It is not known what the original thickness of this pipe was, but the thickness at present is greater than the present Class "C" pipe.

As stated in the first part of this paper, a scheme for reporting leakage in complete distribution systems better than that now used is not readily offered, but at least this may be done. When leakage is reported as so many gallons per day per mile of pipe, it should be noted whether or not this includes leakage from services. The figures mentioned above would indicate that it would be fairer to state the leakage in a distribution system as gallons per day per service than as gallons per day per mile of pipe, as the services were shown, in these cases, to be responsible for ten times as much leakage as the pipe.

DESIGN OF A CITY WATER SYSTEM[1]

By J. D. Galloway[2]

When your committee asked me to give a short paper before your Association, I did not expect that it would be given such an ambitious title. It was my intention to outline briefly some of the points that arose in the design and construction of the water system for the City of Davis and to offer such general comment as might prove of some interest. As a matter of fact, the actual problems that one meets in the design of certain parts of any system throw the best light upon the general principles of design. Everyone has felt the limitations imposed by certain conditions met in practice, together with the necessity of keeping cost within reasonable bounds. In the case of the system for the town of Davis, there were a number of additional parts that I would have liked to have installed for which the money was not available. With this explanation, I will proceed.

When the town took up the subject of a new water system in 1919, it was served in its principal part by the Davis Water Company. This system was the outgrowth from the water supply of a manufacturing establishment, the owner having extended his mains as the town grew. The system was inadequate, and in several bad fires there was practically no water. In the northern part of the town, a company had made an addition and was engaged in building houses. In order to supply the section with water, they had installed an elevated water tank of 50,000 gallons capacity, with a well, a small pump, and some 2-inch service mains. Neither of these two systems furnished sufficient water for the irrigation of lawns in summer and neither one gave fire protection. This condition led the City to vote a bond issue of $75,000 for a complete new system adequate to care for present needs and for some time in the future, and which would also be capable of extension.

After considerable negotiation, the plant of the real estate company was purchased, the elevated steel tank being the major item of cost.

[1] Presented before the California Section meeting, October 26, 1922.

[2] Consulting Engineer, San Francisco, Calif.

The owners of the Davis Water Company opposed the building of the City system, and in the end no part of their works was purchased, partly because the well and other parts were adjuncts of the factory mentioned.

The requirements. At the time when the plans were made, the City had a population of about 1000, with about 225 dwellings and stores. The growth had been steady and constant and the presence of the University Farm indicated further increase in demand. It was the desire of the citizens to have an ample supply of water for domestic and fire purposes and for the irrigation of lawns and gardens, the latter making the town one of the most attractive in that part of the State. Flat rates have been charged and no meters have been installed, although it was advised that some day this program may be changed to avoid waste.

It was believed that, at the time of construction, a daily supply of 250,000 gallons would be ample and this has proved true. I have not kept track of the actual per capita use.

As a matter of fact, the capacity of the principal part of the system was determined by fire requirements. In the business section of the City there are no stores over two stories in height, and the residences are of the usual size in California towns, situated in wide lots with trees and lawns surrounding them. The two methods of fighting fire were canvassed, and the decision was made to depend upon increasing the pressure in the mains at time of fire and taking the water direct from hydrants. The expense of providing and maintaining a fire engine, together with the organization of a paid fire department on the scale required, was too great for the city to undertake. Every town must face this problem. It is recognized that when the population has increased to several thousand, it is cheaper to operate the fire engine than it is to raise the pressure in the mains, but for small places, it is believed better to follow the other method.

The amount of water determined on for fire purposes was 750 gallons per minute, which will furnish three, and possibly four, standard streams. It was assumed that the duration of any fire would not exceed three hours, during which time there would be used 135,000 gallons. The normal pressure required for domestic purposes is in the neighborhood of 40 pounds, or 92 feet. The pressure for fire purposes is from 70 pounds to 80 pounds at the hydrants, and as designed, the maximum pressure at pumping station and in the principal mains does not exceed 100 pounds.

In practically all cases, the length of fire hose needed is about 300 feet, and all houses may be reached by three, and usually by four, streams. In some isolated cases, houses are 600 feet from the hydrants, but such houses may be reached by three hose lines.

The physical situation. Conditions were extremely favorable at Davis for a system upon the best lines. The existing works, which were purchased, worked into the design without trouble. The ground was level throughout, and there were no problems of variable pressure due to differences of elevation. The entire region is underlaid by gravel strata which furnish ample water. There are many wells using water for irrigation, but the region is served by a system of gravity irrigation ditches which will replenish the underground supply, although there may be some lowering of the water plane.

The streets of the city are wide. With one exception, there was no pavement except gravel in the center of the streets. By placing the mains off center, there was little cost of repaving

The elevated tank that was purchased was of good design and construction, but was smaller than deemed necessary for an ample supply. It has been made to serve, however. It was of the proper height, and fitted well into the system.

Design. As finally designed and built, water is drawn from a well about 260 feet deep by a deep-well pump that delivers water into the mains. The tank supply is connected to the system, and water passes to the tank or to the mains, depending on the demand and the amount in the tank. A fire pump is placed in the system, that will raise the pressure to 100 pounds per square inch. The distribution system is made up of cast iron and wrought pipe. Service is given to all houses in town. A connection has also been made with the water system of the University of California Farm that provides emergency service in case of breakdown or fire.

Wells. Two wells have been drilled, 12 inches in diameter and about 260 feet deep. They pass through several strata of gravel lying between thick beds of clay. The lower stratum is 12 to 14 feet thick and yields a good supply of soft water.

The first well was drilled and cased with double stove pipe casing. All went in good order for a while, but the well commenced to draw out sand and mud, and finally the casing collapsed. I might say that this happened after the engineer had departed. There were many theories as to the cause, but the fact of the collapse of this type of casing is the point of note. It was only adopted to save

money, which it did not do. A second well became necessary. This was cased with solid wrought casing, and there has been no trouble.

The casing was perforated with holes about ½ inch in diameter, and, as the gravel is coarse, there has been no trouble from sand.

Well pump. The pump installed was of the deep-well centrifugal turbine type, in five stages, with vertical shaft. The scroll cases were about 10 inches in diameter in the 12 inch casing of the well.

This type of pump was adopted after consideration of the various problems involved. It has been common practice to use horizontal shaft centrifugal pumps, and on account of the necessity of placing such pumps near the water in the well, a large pit has to be dug for the pump chamber. The cost of such pits is considerable, and there is constant trouble from seepage water. Again, the water cannot be followed down in the event that the water plane falls.

Although the efficiency of the turbine vertical shaft pump is somewhat less than the horizontal type, it was preferred because it could be placed on the floor of the pump house at ground level, thus avoiding all the disadvantages noted above.

As installed, the pump has a capacity of 500 gallons per minute against a head below ground of 40 feet maximum draw down of water, and 104 feet above ground, a total of 144 feet maximum head. The suction end of the pump was placed about 60 feet below ground. It is operated by a 30 horsepower, 440 volt, 3 phase, 60 cycle, alternating current motor, having the usual overload ratings. The efficiency of the pump is over 50 per cent.

Under normal operation, the pump delivers water into the mains to which the elevated tank is connected, so that the entire system is open. A float switch in the tank starts and stops the pump motor, which thus enables the water in the tank to be maintained at constant level and pressure. The flow of water from the tank and pump is through a loop around the fire pump.

Fire pump. The fire pump is a single stage horizontal centrifugal pump of 1000 g.p.m. capacity when receiving water at 40 pounds pressure at the suction end and delivering it at 100 pounds pressure at the discharge end. The pump is placed directly in line between the outgoing main and the well pump or the tank. By closing the valve in the by-pass around the fire pump and opening the one between the two pumps, water passes directly from the supply to the mains, being raised in pressure by the fire pump. The fire pump is provided with a relief valve with a visible discharge, the valve

being adjustable for different pressures. All of the pumping equipment was made in accordance with the requirements of the Board of Fire Underwriters.

It was noted above that the estimates for water reserve called for a tank of 100,000 gallons capacity. This amount was desired largely as a reserve in case of fire, the amount that could be drawn from the well for fire supply not being known. The plans for the works called for a wooden tank of 100,000 gallons capacity, situated at the ground level. This tank was to be kept filled with water which would be passed into the well in case of fire and thence through the well and fire pumps to the mains. It was merely a reserve for supplying any deficiency in the well. Owing to limited funds, this tank was not installed. The 50,000 gallon tank and the well have been sufficient to supply all the water needed since.

The electric power supply. In most systems it has been found necessary to install a steam or gasoline engine driven fire pump as a safety factor, owing to the possibility that electric service lines to the pumping station would be out of service in time of fire. The funds available at Davis did not permit this, and the arrangement was made to have the lines from the power company's sub-station to the pumping plant in duplicate. These duplicate lines reach the station by separate routes, one on the outskirts of the town where there is little danger from interruption. The sub-station is on the edge of town, and the fire risk is not great.

University farm emergency connection. Adjacent to the City is the farm of the University of California. This Farm has a complete system of water supply, with elevated tanks for fire service and pumps to correspond. An interchange agreement was made between the City and the University, and the mains were connected. In the case of the failure of the City plant for any reason, water can be sent to the City mains from the Farm, and vice versa. This arrangement furnishes additional security in case of fire.

The distribution system. The plans for the distribution system are simple. The town is compact and of a rectangular form. The line of the Southern Pacific separates an eastern section from the main part of the City to the west. As designed, the principal mains are 6 inches in diameter cast iron pipe, the supply from the pumping plant to the main being 8 inches in diameter. The principal mains are laid out on the loop system, the loop for the main part of town enclosing an area four blocks wide and five blocks long. Outside of the loop on all sides is one tier of blocks, the longest being about 500 feet. Inside the loop a cross connection of 6 inch pipe was added for supplying hydrants. On the eastern part of the city there is

another loop two blocks wide and three blocks long, with an outside tier of one block wide on all sides. In this way, nearly all blocks in the City have a 6 inch main on at least one side, and any hydrant receives water from two directions by 6 inch pipe. On the advice of Mr. Elliott, all joints in cast iron pipe were made with Portland Cement mixed very dry and rammed into place. Under test, these joints were practically water tight.

On streets not served by the 6 inch mains, there is placed a 2 inch wrought pipe for services, those outside the loop being connected at the ends and forming minor loops, so that there are no dead ends, with three exceptions. Inside the loops, the 2 inch mains are connected at each end to the 6 inch mains. In this way, no house service is over 800 feet from the 6 inch mains, and all may receive water from two directions.

There is a complete system of valves for isolating sections of the mains. Valve boxes are of redwood, the expectation being to replace them with more substantial boxes when the streets are paved.

Twenty-four Cory hydrants with 6-inch connections to the mains were placed. Each hydrant has two standard hose connections. As sections of the mains can quickly be isolated by the main valves, no gate valve was placed between the hydrant and mains.

As noted before, house services were not metered, but in time this will be brought about. Meters were omitted for the reasons given, but I am of the opinion that metered services are the only means of preventing waste and of securing equality in payments for water used.

The design of the Davis system was simple. The only points of interest are the use of the vertical shaft deep well pump and the omission of the usual deep pit for the pumping apparatus. The use and position of a centrifugal pump for raising the pressure from normal up to fire pressure is somewhat different from general practice.

The system was built in 1920 at a period of high prices. It has given general satisfaction to the citizens. We were forced to economize wherever possible, but we did obtain cast iron for the principal mains, and the other parts are of the best quality. Other waterworks men have probably had to economize at times and will appreciate this statement.

I am aware that I have offered nothing new in design. I think, however, that the Davis plan comprehended most of the problems met with in the water supply of small towns and, as such, may have been of interest to this audience.

ZINC CONTAMINATION IN DRINKING WATER

By Charles D. Howard[1]

Apparently zinc, due to galvanized pipe corrosion, is much more frequently present in drinking water than is commonly suspected. Aside from the question of possible deleteriousness there is an annoyance attaching to its presence in more than traces that is akin to the iron nuisance.

Though not invariably done as a matter of uniform routine, this laboratory has made many hundreds of zinc determinations covering samples in connection with which such information seemed worth while. In many cases this was in consequence of complaints; in others, the test was made in connection with findings of large proportions of nitrites or free ammonia, it being frequently found that these are due to the reducing action of zinc on nitrate, in which case these data of course do not have the sanitary significance that would otherwise attach to them.

Dissolved air, and particularly carbonic acid, such as is apt to be found in appreciable amounts in ground water sources, are prone to cause zinc solution. Especially is there apt to be this trouble with systems utilizing compressed air. Hard waters also attack zinc, and excessive chlorides or nitrates are practically sure to exert a pronounced corrosive effect.

Waters carrying as much as 5 p.p.m., of zinc, which are very commonly encountered in this locality, are generally characterized by turning opalescent and exhibiting a "greasy film" on boiling, and the walls of cooking utensils, water tanks, etc., soon take on a fine grayish-white, paint-like coating. This situation may continue in the new system from a few months to a few years, when the appearance of a faint astringent taste, together with a browning of the original gray-white coating and the settling out of a reddish sediment on the bottom of the tea kettle, announce the advent of the second stage of the householder's water pipe troubles.

[1] Chief, Division of Water Supplies, Foods and Drugs, New Hampshire Board of Health.

We are still lacking the definite clear-cut knowledge we should have concerning the hygienic significance of the daily ingestion of small amounts of zinc as a contamination of drinking water. While we do know that it is not cumulative in its action and that it obviously does not occasion anything like the poisonous effects of lead, yet it would appear, from a review of what little literature exists touching this subject, that the opinions expressed are very largely guess. So far as can be found the matter has never been studied in any systematic scientific way.

In the report of the Massachusetts Board of Health for 1874, Doctor Boardman expresses the belief that the oxide and carbonate of zinc as occurring in drinking water are absolutely harmless, declaring that "even if all the zinc in solution were in the form of chloride, the most active poison of the zinc salts, the amount would still be insufficient to endanger health." As waters carrying an amount of zinc which, if expressed as chloride, would be equivalent to as much as two grains per gallon, are not especially rare, there are probably no modern sanitarians who would subscribe to the last part of this statement.

In later reports of the Massachusetts Health Department (1900 and 1902) the conclusion is expressed that "as far as known" the amount of zinc thus ingested is not sufficient to have any effect upon the health of the consumers.

Thresh[2] states "there is no doubt that waters containing traces of zinc are used continuously for long periods without causing any obvious ill effects." Hazen[3] cites the case of the use by the city of Brisbane, Australia, of rain water containing 17.1 parts per million following storage in galvanized iron tanks, without any harmful results being observed. Harrington,[4] in referring to the zinc contamination as sometimes encountered in evaporated apples and as formerly met with in canned foods, suggests that "we have no evidence that these small amounts are of the slightest sanitary importance." Nevertheless this view of the matter does not find practical support today, as witness the now not uncommon regulations prohibiting the use of zinc-lined containers for food stuffs and the precautions required to be observed in manufacturing to guard against zinc contamination of foods.

[2] "Examination of Water and Water Supplies."
[3] Engineering News, April 4, 1907.
[4] "Practical Hygiene."

Sollman[5] also believes that there is little to be feared from the continued ingestion of zinc salts, maintaining that "there is no danger of chronic poisoning." The United States Dispensatory, on the contrary, declaring the salts of zinc to be poisonous, "though not to the same extent as those of lead" asserts that zinc should never be used for culinary vessels, as it is soluble in the weakest acids.

Practically all of the recorded cases of deaths or active poisoning due to zinc have involved either the chloride or the sulphate, the former being a pronounced caustic while the latter is recognized as an irritant. Haines[6] refers to a case of death having resulted due to the caustic action of zinc chloride following administration of as little as six grains.

Mason[7] believes that certain waters can furnish dangerous quantities of zinc and suggests the desirability of determining action before installing galvanized pipe. This writer points out that, even on the assumption that the presence of zinc has no sanitary significance, as claimed by some authorities, its being there is nevertheless undesirable.[8]

Emerson[9] claims, as do others, that as zinc is very apt to be contaminated with lead or arsenic, it is highly probable that many of the symptoms attributed to zinc poisoning are in reality but manifestations of these metallic contaminations. Thompson,[10] referring to the extensive use of zinc oxide in the industries, states that the inhalation of this substance by workmen results in disordered digestion and tends to give rise to what is known as "zinc founders ague." This writer also cites a "nearly fatal" case of zinc poisoning attributed to melted ice drawn from a zinc-lined refrigerator being given to a small child, and he urges the adoption of warnings against "drinking or eating anything which has come in direct contact with zinc."

Finally, as opposing the views in this connection of certain German observers, Rideal,[11] an English authority, declares that the use of water from cisterns of galvanized iron has caused symptoms of irritant poisoning.

[5] "Text Book of Pharmacology."
[6] "Text Book of Legal Medicine and Toxicology"—Peterson and Haines.
[7] "Water Supply."
[8] "Examination of Water."
[9] "Toxicology."
[10] "Occupational Diseases."
[11] "Water and Its Purification."

Notwithstanding this conflicting testimony, it is believed we are justified in seriously questioning the hygienic fitness of any water showing more than traces of zinc. It should be obvious that, if it is recognized that foods, only small amounts of which may be eaten, may and have taken up sufficient zinc, as a result of storage in galvanized receptacles, to cause acute illness, it is an inconsistency to suppose that the free daily consumption of water uniformly carrying smaller yet substantial amounts of this metal can be devoid of any sanitary significance,—granting even the modifying influence due to a possible difference in the form of combination. At any rate it is believed that the subject is worthy of closer study and that it would be worth while to make the zinc determination more frequently than apparently is the present practice with our water laboratories.

It is our observation that up to 5 p.p.m. is very common in the case of ground waters conducted through galvanized iron pipe, and that 10 to 15 parts is rather frequent, especially in comparatively new installations. As already indicated, such waters are a nuisance to the housewife, irrespective of any question of deleteriousness.

For the routine estimation of zinc the official method is too cumbersome to be practical. A rapid nephelometric procedure, based upon comparison of the turbidity due to ferrocyanide with that of a standard zinc solution, has been in use in this laboratory for many years. For the type of clear and practically iron-free waters as received by us it is of sufficient accuracy for the purpose, and it has the advantage that it may be carried out in five minutes. While results are recorded by us to tenths per 100,000, through the use of a turbidimeter much closer readings would undoubtedly be practicable. The details are as follows:

Standard zinc solution. Dissolve 1.2446 grams freshly ignited zinc oxide in a little dilute sulphuric acid and dilute to 1 liter, making 100 cc. of this solution to 1000. One cubic centimeter is equivalent to 0.0001 gram zinc.

Potassium ferrocyanide solution. Use a 10 per cent solution which is fairly fresh, i.e., not showing any appreciable greenish-blue tint.

Sulphuric acid (1–2). Method: To 50 cc. of the water contained in a 50 cc. Nessler tube add 1 cc. of the dilute acid *followed by* 1 cc. of the ferrocyanide. Mix and let stand about five minutes to secure maximum development of turbidity. At the same time prepare standard tubes. Read by viewing downward against a dark background, holding tubes at an angle of about 45 degrees. Where iron is present this should be removed with ammonia in the usual way and the test applied to the cooled filtrate. With waters of high zinc content use proportionately less, diluting to 50 cc. with distilled water.

PROGRESS REPORT OF COMMITTEE ON INDUSTRIAL WASTES IN RELATION TO WATER SUPPLY[1]

With the rapid growth of industries the injurious effects of industrial wastes on water supplies and water purification processes are becoming more and more important. Serious trouble from this source has already been experienced in numerous places, as this report shows.

EFFECT ON PUBLIC WATER SUPPLIES

Certain wastes, alone or in combination, may have beneficial effects on the water supply by disinfecting action or clarification, but most industrial wastes are detrimental to water supplies. The injury depends upon the character and relative quantities of the substances discharged, with effects which may be classified as follows:

1. Suspended or colloidal mineral matters which increase turbidity and add to the difficulty and expense of coagulation or of filtration, as, for example, coal and ore washing wastes.
2. Dissolved mineral matter impairing the quality of the water and increasing the difficulty and expense of water purification, as, for example, acid mine drainage and salt water from oil wells.
3. Vegetable and animal organic matters in solution or in suspension, which increase the color, turbidity, suspended matter and bacterial content, thereby increasing the difficulty and expense of water purification, as, for example, beet sugar refinery wastes and tannery wastes.
4. Taste and odor producing substances, either organic or mineral in nature, as, for example, phenols in the wastes from gas and coke manufacturing, and sulphite liquors from paper pulp mills.

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[1] Prepared under the direction of the Council and contains the more essential features of the preliminary report made by this committee at the Philadelphia convention, May, 1922. To the information then in hand a few additions have been made, particularly with respect to a summary of the important lawsuit brought by the Mountain Water Supply Co., a subsidiary of the Pennsylvania Railroad, seeking to enjoin the discharge into its storage reservoir on Indian Creek in Fayette County, Pennsylvania, of acid mine water from the Melcroft Coal Co. and others operating coal mines in the Indian Creek Valley above the reservoir.

5. Substances, either organic or mineral, tending to stimulate growths of organisms and thereby increase the difficulty and expense of treatment, as, for example, organic sulphur compounds in wool scouring wastes, and mineralized nitrogen from oxidation of organic wastes of various kinds.

6. Harmful bacteria, as, for example, the anthrax bacilli in tannery wastes.

7. Poisons, as, for example, cyanide from the cyanide process of gold extraction.

The Committee has obtained information through a questionnaire from public officials, water works managers and other sources indicating that 248 water supplies, widely distributed throughout the United States and Canada, have been affected by industrial wastes. The information obtained is valuable but incomplete. Accordingly members of the Association who have not already furnished the Committee with data of this nature with which they are familiar are urgently requested to do so. It is only by such general coöperation that such studies will yield the most useful results. The character of information desired is indicated by the following notes on the general features of the data already gathered.

Recent literature bearing on the subject has been reviewed by your committee and a tentative bibliography is appended to this report.

SUGAR REFINERY WASTES

The water supplies of Defiance, Nepoleon and Toledo, Ohio, derived from the Maumee River, encountered disagreeable tastes and odors during the winter months of 1920 when the stream was completely frozen over (25). The trouble was attributed to oxygen depletion and anaerobic decomposition of vegetable organic matter, believed to be due in large part to wastes from beet sugar refineries. Color and bacteria in the river water increased and ordinary purification facilities, including storage, aeration, filtration and chlorination, were only partially effective.

Along the same line the Michigan Department of Health reports fish killed and offensive odors created in the Raisin River below a large beet sugar plant (18), though no water supplies were affected in this case.

COAL WASHERY WASTES

In 1807 the pollution of the Philadelphia water supply by finely divided coal and dirt from washing of anthracite coal was a subject

of litigation (2). Water from some of the coal washeries contained over 63,000 parts per million of suspended solids. Other water supplies in the anthracite regions of Pennsylvania and West Virginia and in the southern bituminous fields have been affected in a similar manner.

ACID WASTES FROM COAL MINING

The acid wastes from coal mining operations, by reason of the number of supplies affected, probably outrank all other sources of industrial pollution. In Pennsylvania alone it is estimated that over 850 million gallons of water are pumped each day from the mines of the anthracite field and nearly as much more from the bituminous district. It is estimated that these waters and the discharge from the washeries carry more than 3000 tons per day of free sulphuric acid and acid salts. In this state 96 public water works, supplying nearly 45 per cent of the total population, are affected. The estimated cost to the state of such pollution is more than eight million dollars annually (26). At McKeesport, Pa., the Youghiogheny River, formerly used for water supply after filtration and softening, became polluted to such an extent as to necessitate a change in the source of supply (5). The acidity of the river water was at times as high as 390 parts per million. The Pennsylvania Department of Health reports other cases in the state where a change of supply has been made necessary on account of heavy acid pollution.

In West Virginia, the Department of Health reports 10 water supplies affected by acid mine drainage.

Unneutralized acid mine drainage, although tending to reduce bacteria by disinfection, affects the appearance of the stream, destroys fish life, causes corrosion of pumps, distribution systems and house plumbing and entails extra expense for treatment. One great difficulty is that old and abandoned coal mines continue to yield acid drainage for years, due to the extraction of sulphur by water flowing through gob piles both within and without the mines.

Neutralization of mine drainage with lime, followed by filtration, has been found effective at some places but the resulting sulphate of lime may assume such proportions as to affect prejudicially the water for steam raising purposes. Softening by soda ash is sometimes resorted to, but is expensive and has certain limitations in practice (35).

MOUNTAIN WATER SUPPLY COMPANY VS. MELCROFT COAL COMPANY

On December 26, 1922, Judge Van Swearingen of the Common Pleas Court of Fayette County, Pennsylvania, handed down an opinion and decree refusing an injunction sought by the Mountain Water Supply Co., a subsidiary of the Pennsylvania Railroad, to restrain coal companies operating in Indian Creek Valley above the reservoir of the Water Co., from permitting mine water to flow into the Indian Creek or its tributaries. This litigation began in 1920 when the plaintiffs filed a Bill in Equity against the Melcroft Coal Co., and it is of great importance in relation to the pollution of streams by acid wastes resulting from coal mining operations. Some of the basic elements of the case are taken from the extensive opinion of the court, embracing some 98 typewritten pages, as follows:

1. Indian Creek has a drainage area of about 130 square miles. Its head waters are in Westmoreland County and it flows in a southwesterly direction across Fayette County, entering the Youghiogheny River about 10 miles above the city of Connellsville. Up to ten or fifteen years ago this watershed was of rural character, occupied by a population of about 2500, who were largely engaged in farming operations and who operated a few small country mines for local use. The waters of Indian Creek were then fairly pure and well adapted for domestic use and steam-raising purposes.

2. About 16 years ago the Water Company built a storage reservoir holding 251 mg. and also about 141 miles of pipe lines for distributing this water along the branch lines of the Pennsylvania Railroad extending as far west as Pittsburgh. The dry weather flow of this stream is nominally rated at 6.5 million gallons daily, but, with the aid of storage, something like 10 million gallons daily have been delivered to the railroad and to the Westmoreland Water Company for supplementing its limited supply for industrial and domestic consumers in the Greensburg district.

3. When the reservoir was built, it was known that the watershed was underlaid by seams of the lower productive measures of bituminous coal. The lower Kittanning seam ranges from about 36 to 58 inches in thickness and above the storage reservoir there are about 43,000 acres of this coal vein. Coal mining has been quite extensively developed with the aid of a railroad now extending well toward the headwaters. The tonnage of coal shipped by rail from

this valley prior to 1914 approximated 15,800 tons in the aggregate, but later activities increased the output in 1918 to 181,000, in 1921 to 329,600 and during the first half of 1922 to 300,000 tons. The mined-out area increased from about 3 acres in 1914 to about 50 acres in 1922. The population is now estimated at from 6000 to 6500, mostly in villages near the stream.

4. The flow of mine water depends upon rainfall and other local conditions, but approximated 1760 gallons daily per acre mined out. This flow diminishes somewhat after mining operations cease but the acid content due to sulphuric acid may continue high and even increase due to drainage passing through the bone coal and gob piles.

5. The reservoir water now needs filtration to make it suitable for domestic use and for some ten years the expected acidity of the mine water will not require neutralization and softening to a greater extent than is now practiced by many public water companies and municipalities.

6. After a period of ten years the construction of storage dams on the upper parts of Indian Creek or some of its tributaries may provide diluting water so that the water of the present reservoir may be handled by usual and customary methods of treatment to make it fit for domestic and industrial purposes.

7. In considering the remedial measures it was held that it is not feasible or practicable for any or all of the coal operators of this valley to treat the mine water at the mines and that such treatment would entail an unreasonable expenditure. Further, on account of practical and economical difficulties it is not feasible for the coal operators to carry mine water below the storage reservoir.

8. The court ruled that neutralization or softening or other treatment of the Indian Creek water by the Water Company if, when and as necessary, will not entail an unreasonable burden on the plaintiff Water Company.

This decision is in line with the Sanderson case (113 Pa. 126) decided nearly forty years ago in favor of a Coal Company as against a lower riparian owner through whose estate flowed a brook which was fouled by coal mine drainage and the water made unsuitable for domestic purposes. In the Melcroft case, the court balanced equities under local conditions where the coal mine operators were held to be pursuing a proper and natural use of their lands, with cost of remedial measures approaching property confiscation and

where the Mountain Water Supply Company was held to have no power of eminent domain and with the Westmoreland Water Company viewed as nothing more than a purchaser of water from the Mountain Water Supply Company. The State Department of Health of Pennsylvania has no jurisdiction in respect to coal mine drainage or discharges from tanneries. This litigation related therefore to common law and not to statutory proceedings.

GAS AND BYPRODUCT COKE WASTES

The great increase in the coal distillation industry has had a marked and widespread effect on water supplies, by imparting disagreeable tastes and odors to the water, particularly after chlorination. The State Boards of Health of Indiana, Illinois, New York, Ohio, Pennsylvania, West Virginia and Wisconsin report altogether some 50 water supplies affected in this way. The industrial plants giving rise to this kind of pollution are gas works, producer gas plants, byproduct coke ovens and manufacturies receiving the products of these plants and extracting chemicals by further distillation and separating processes. The objectionable wastes come very largely from the tar separators, ammonia, benzol and naphthalene stills, together with the residues and sludges from various parts of the plant.

It is becoming generally recognized that the odor and taste from these "creosotes" or "phenols" is greatly accentuated by chlorination of the water supply due to formation of chlorphenols or other substitution products.

The tastes produced have been variously described as "chemical," "creosote," "hospital," "medicinal," "carbolic acid," or "iodoform." Persistence of the taste in dilution as great as 1 part of waste to 10 million parts of water or after passage by stream as far as 70 miles has been reliably reported.

At Milwaukee obnoxious tastes in the chlorinated water supply were shown to be due to coal tar derivatives discharged from coke and phenol plants directly or indirectly into Lake Michigan from which the city takes its water supply (10). Tastes in the chlorinated water were reported in dilutions of one part of phenol to 500 million parts of water.

Pollution by coal distillation wastes have been studied in several states of the middle west and along the Atlantic Coast in the last few years.

An extended series of tests to determine the cause of tastes and odors in the Cleveland water supply (22) led to the conclusion that they were due principally to the waste liquors from ammonia stills of by-product coke oven plants.

An extensive joint investigation has recently been made by the city of Chicago and the Chicago Sanitary District to determine the effect of pollution, including coal tar wastes, entering the Calumet River and Lake Michigan upon the quality of the water supply taken from the 68th Street and Dunne cribs. The conclusion reached was that the probable concentration of polluting material, reaching the two cribs, was insufficient to cause taste in the supply. In Appendix IV of the report of the Chief Engineer of the Chicago Sanitary District, are given results of tests to determine the lowest dilutions of various phenol wastes required to give taste with chlorinated unpolluted lake water. Wastes from gas and coke industries could be detected in dilutions of 1000 to 100,000 volumes of lake water. The intensification of the tastes due to chlorine was found to be much less than reported by observers in other localities.

No satisfactory method for water purification has been found to eliminate the tastes and odors due to phenol wastes. At Youngstown, Ohio (19) excess lime treatment is reported as being successful in reducing objectionable odors and tastes. At Newcastle, Pennsdlvania, a considerable reduction of the phenol content of the raw water by the use of iron and lime as coagulant in connection with filtration has been reported.

For taking care of the wastes at the source the West Virginia Department of Health reports success in one case by pooling in porous ground.

The Pennsylvania Department of Health has been obliged to take measures to prevent entry of such industrial wastes in the streams above the water supply intake. A practical and effective remedy in some cases has been found in the evaporation of the objectionable wastes from by-product coke plants by using them for quenching the glowing coke. In one case the residual wastes from a water gas plant remaining after re-circulation of the settling basin effluent through the gas scrubbers were treated with ferrous-sulphate and filtered through coke breeze, after which it is used for boiler water (21).

Plants suggested in Wisconsin for the treatment of gas house wastes have been described by Mr. E. J. Tulley (9). They comprise reten-

tion units for separation of tar and light oil, aeration, chemical treatment with lime or copper and lime, sedimentation and double filtration through coke contact beds and gravel sand filters. No information is available as to the practical workings of this process.

In connection with the activated sludge process of sewage treatment at Milwaukee, Mr. Copeland has found (7th annual report of the Sewage Commission, 1920) that the activated sludge process was able to handle sewage containing considerable amounts of phenol and that the process removed a substantial portion of them. The results of these tests indicate that the activated sludge plant now being constructed in Milwaukee will materially protect the Lake water supply from tastes produced by phenol discharge into the city sewers.

WOOD DISTILLATION WASTES

Plants employing the destructive distillation of wood for the recovery of wood alcohol, acetate of lime, creosote oils and charcoal are reported as affecting water supplies in a number of the states and in the Province of Quebec.

Troublesome wastes consist of the spent still liquors, residues from the stills and certain sludges and crude tars. These wastes impart a pronounced "smoky" taste and characteristic "creosote" odor. Unlike the coal tar phenols, the taste and odor from the wood distillation wastes appear to be intensified little by chlorination.

The Wisconsin Department of Health reports tastes and odors from wood distillation plants to have occurred mainly during the winter months when the lakes were frozen.

In Pennsylvania evaporation of the wastes, discharge into abandoned quarries or distribution on the gound surfaces at distances from the streams, are methods found effective according to the Department of Health.

At Marquette, Michigan (28), the remedy proposed was the evaporation of the most objectionable wastes to 25 per cent of their original volume and utilization of this residue as liquid fuel.

A disagreeable taste in the water supply of Elizabeth, New Jersey, was found (16) to be due to creosote oils spilled around the building and washed into a brook contributing to the water supply. In this case chlorination was found to increase the taste materially, but aeration caused a marked reduction.

Aeration by means of fine spray nozzles is being tried at one Pennsylvania water plant for the elimination of tastes and odors due to wood distillation wastes, after experience had shown that ordinary aeration followed by filtration failed to eliminate the disagreeable qualities.

CORN PRODUCTS WASTES

One water supply in Indiana is reported as being polluted by wastes from gluten settlers at a corn products factory. These wastes affected the appearance of the raw water, caused a marked increase in bacterial growth and imparted an odor and taste. Increased amounts of chemicals were required in coagulation and the chlorine dose had to be raised. A testing station for the experimental treatment of corn products wastes is being operated by the Chicago Sanitary District at Argo, Illinois, to determine the best method of treating such wastes.

WASTES FROM MANUFACTURE OF DYES AND INTERMEDIATES

Two water supplies in New Jersey are reported to have been affected by the wastes from the manufacture of dyes and intermediates, the trouble manifesting itself in an objectionable taste in the water.

The New Jersey State Department of Health (16) reports that, as the result of injunction proceedings brought to prevent the pollution of the Rahway River, the source of water supply for the city of Rahway, by wastes from the manufacture of dyes, the manufacturing concern is now treating the industrial wastes by the method of chemical precipitation with lime and copperas, followed by filtration through sand.

WASTES FROM MANUFACTURE OF MUNITIONS

The wastes from munitions plants are in much the same class as those from dye works. At Kenvil, New Jersey, the State Department of Health found (16) that the "ether" and "chemical" tastes in the water from individual wells on the outskirts of the town were caused by wastes from a munitions plant taken in solution by storm water and gradually percolating into the underground stratum in which the wells are located. A new source of water supply will probably be necessary.

The New York State Department of Health reports one water supply affected by picric acid from a TNT plant. This imparted a yellow color to the water and produced very objectionable odors and tastes against which the ordinary purification facilities were ineffective.

The Superior Board of Health of the Province of Quebec reports one water supply affected by acid wastes from a powder works. The remedy consisted in neutralizing the acidity prior to the discharge of the wastes.

LEATHERBOARD WASTES

The Board of Health of New Hampshire reports one water supply affected by leatherboard wastes which clog the slow sand filter. The amount of suspended solids discharged into the stream has been greatly reduced in recent years by sedimentation.

METAL PICKLING AND GALVANIZING WASTES

Seven water supplies in Ohio are reported to be affected by metal pickling and galvanizing wastes. The objectionable substances consist of free acid and acid salts which affect the appearance of the raw water, and interfere with coagulation. Lime treatment and filtration have been found effective, although soda in addition would be required to offset the increased sulfate hardness resulting from neutralization.

METALLURGICAL MINING WASTES

In the mining industry considerable ore is milled by the oil flotation process from which comes a very large volume of waste consisting mostly of finely pulverized rock. This material is usually ponded without difficulty, but one water supply in California is reported by the State Board of Health to have been affected. Increase of turbidity was the only objectionable effect in this instance.

In Colorado some of the most beautiful streams have been ruined by the tailings from mines against which pollution some court injunctions have been issued, as is true of the cyanide process for ore extraction where leaky tanks might drain into the source of water supply.

In California the pollution of water supplies by the cyanide process has been occasionally alleged although not definitely established.

The California Board of Health reports one case where the spent liquors from the plant of a copper company appeared to have a beneficial effect by reason of its disinfecting action on the sewage contaminated river used as a source of water supply.

OIL WELLS—CRUDE OIL AND SALT WATER

Crude oil spilled into water supplies affects appearance, odor and taste, interferes with coagulation, filtration and chlorination. The slow sand filtration plant at Pittsburgh has been reported as troubled with paraffins which encrust the sand grains and interfere with normal operation of the filters (30).

By far the most serious effect on water supplies of oil well operation is that due to the discharge of salt water from the wells with the oil. The salt wastes affect palatability of the water and limit the usefulness of the water for boiler use and industrial purposes. The trouble from salt pollution is quite widespread and has been the subject of litigation in many states and has resulted in more than one city changing its source of supply.

In Oklahoma not only the streams are reported to be generally affected but the ground water as well, by reason of ineffectively plugged and abandoned oil wells (26).

OIL REFINERY WASTES

Much trouble is reported from Kansas and other oil producing states on account of the waste waters from oil refineries which sometimes affect the water supplies by causing very serious tastes and odors. The Kansas State Board of Health reports many Kansas supplies affected by the wash water from the agitators in which crude gasoline and kerosene are purified. Independence, Missouri, is reported to have been affected by oil refinery wastes. Water supplies at the south end of Lake Michigan at East Chicago and Whiting, have been similarly affected (11) and (27). Other cases of pollution by oil refineries are reported from Pennsylvania, Texas and the Province of Quebec.

PAPER PULP MILLS

Water supplies in a number of states are reported as having trouble with wastes incident to manufacture of woodpulp. The wood fibre itself has caused some trouble, but the greatest damage done to the

stream by mills of this character is due to the discharge of waste sulphite liquor which imparts a very high color, difficult to remove, even when greatly diluted. The presence of these wastes retard coagulation, call for a greatly increased dose of coagulant and of chlorine required to sterilize. Aeration after coagulation and sedimentation has been of value, in at least one instance, in treatment of a water supply contaminated with sulphite waste. Disagreeable tastes and odors are caused by sulphite wastes, if present in appreciable quantities.

SAWDUST

The State Department of Health of New Hampshire reports that in a few instances the operation of saw mills has affected water supplies by imparting color.

The State Board of Health of Oregon reports that chlorination plants, located in small cities, have been affected by sawdust discharged from sawmills on the streams used for water supply.

TANNERY WASTES

Replies to our questionnaire show one supply in New York, two in Pennsylvania and four in West Virginia affected by tannery wastes. This number is probably far short of the number of supplies more or less affected. Tannery wastes contain much organic matter and markedly increase the color and in some cases the turbidity and bacterial content of the supply.

Treatment of these wastes at the source has been partially successful in West Virginia where lagooning is used. Tannery wastes are susceptible to treatment by sewage purification processes. There are a number of such treatment plants in Massachusetts where well purified effluents are produced.

Studies made by the United States Public Service and published in Bulletin 100 (8) indicate that tannery wastes may be treated so that the effluent will not unduly affect water purification plants provided the same factors of time and dilution are allowed as considered necessary in dealing with a water supply containing sewage. Consideration must be given to possible danger from anthrax germs when dealing with tannery wastes.

TEXTILE WASTES

Spent dye liquors, scouring and washing wastes and bleach liquors are the substances reported as most troublesome from textile industry. These wastes affect the appearance and oxygen demand of the stream and have been the cause of tastes in water supplies.

SOLUTION FOR WATER SUPPLY PROBLEMS DUE TO INDUSTRIAL WASTES

There are three general methods of attacking problems of water supply resulting from the discharge of industrial wastes.

1. Treatment of the polluted water.
2. Treatment of industrial wastes prior to discharge.
3. Elimination of industrial wastes from the source of water supply.

There are some kinds of industrial waste which may be handled by water purification plants without serious overload or impairment of the quality of purified water. In other cases, the pollution may be of such nature and of such amount as to necessitate special treatment at the water purification plant with closer supervision and increased operating cost. There are some wastes, however, which are of such obnoxious character that ordinary purification plants are not able to handle them successfully. Feasibility of recovery of valuable byproducts from industrial wastes must not be overlooked.

Preventive measures are needed to control the discharge of industrial wastes into existing or potential sources of water supply. Due regard must be had for established industries and arbitrary and unreasonable measures should not be used against them. The problem must be considered from the broad viewpoint of public welfare.

When these problems are confined to a single state the control should be placed in the hands of State Boards of Health and new laws and modification of existing laws should be enacted wherever necessary to enable these boards to control effectively the situation. Adequate appropriations for field and laboratory investigations are essential. The policy of many states must be broadened in these respects in order properly to protect the public interests. Investigation should precede legislation and drastic action should be employed only when found necessary.

In the case of interstate problems of this kind the Federal government should not be overlooked. The United States Public Health Service has already made extensive investigations along this line and should be fortified with adequate legislation and appropriation to carry out the work already started.

A study of existing and needed legislation, local, state and federal, relating to the pollution of water supplies by industrial wastes, has not been completed by your committee. Attention is called to an excellent digest of judicial decisions and a compilation of legislation relating to the subject of stream pollution prepared by Montgomery and Phelps, and published by the United States Public Health Service as Bulletin No. 87 in November, 1917.

While it is important to set up wisely drawn statutes and to arm central health boards with reasonable authority, it is not to be overlooked that large industries frequently resort to the courts and thus defer for a long time a final settlement of the problems of industrial wastes disposal. The latter have their economic aspects and in Europe such problems were not much advanced until District Drainage Boards or River Conservancy Boards were established for bringing about coordinated cooperative effort so that all concerned could proceed with a unified progressive policy and working program. Owners of industrial plants are given representation on these boards and as it is largely their money which is to be spent for treatment of these wastes, it is no more then fair that they should have a voice in remedying all types of pollution in a given valley or locality. A summary of the experience of some of the European Rivers Boards will be given in a later report.

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THE RELATION OF THE FLOOD CONTROL WORKS OF THE MIAMI CONSERVANCY DISTRICT TO POWER DEVELOPMENT[1]

By Chas. H. Paul[2]

The flood of March, 1913, was the greatest ever recorded in the Miami Valley, Ohio. Large sections of the business and residential district of Dayton and Hamilton were inundated to depths of 10 to 12 feet. At Dayton, the levees guarding the down-town district were overtopped by 6 feet or more, and the peak flow through the city exceeded the capacity of the river channel by nearly 300 per cent. Similar conditions existed in the other cities and towns in the valley. The property loss was estimated at $100,000,000.

Immediately following the flood, relief committees were organized in the different cities, and plans for prevention of future floods began to be formulated. Each community worked independently at first, with the idea that each would work out its own salvation, the first thought in the mind of every one being that the desired results could be accomplished by channel enlargement. Soon after systematic engineering study was begun, however, two things became apparent; first, that channel enlargement alone, to the extent required, was not practicable; second, that one city by itself could not adequately protect itself, and that it was a job for the whole valley to undertake as a unit. A combination of channel enlargement and retarding basins was the final solution of the problem.

But there was no practical way, under the Ohio laws then existing, for the valley to organize as a unit and carry through a project such as this. It became necessary, therefore, to enact legislation to permit and protect such an organization. The Conservancy Act of Ohio, passed in 1914, paved the way for the organization of the Miami Conservancy District, which was effected soon thereafter.

A map of the Miami Valley (fig. 1) shows three main branches of the river coming together at the City of Dayton. From west to

[1] Presented before the Central States Section meeting, November 2, 1922.

[2] Chief Engineer, Miami Conservancy District, Dayton, Ohio.

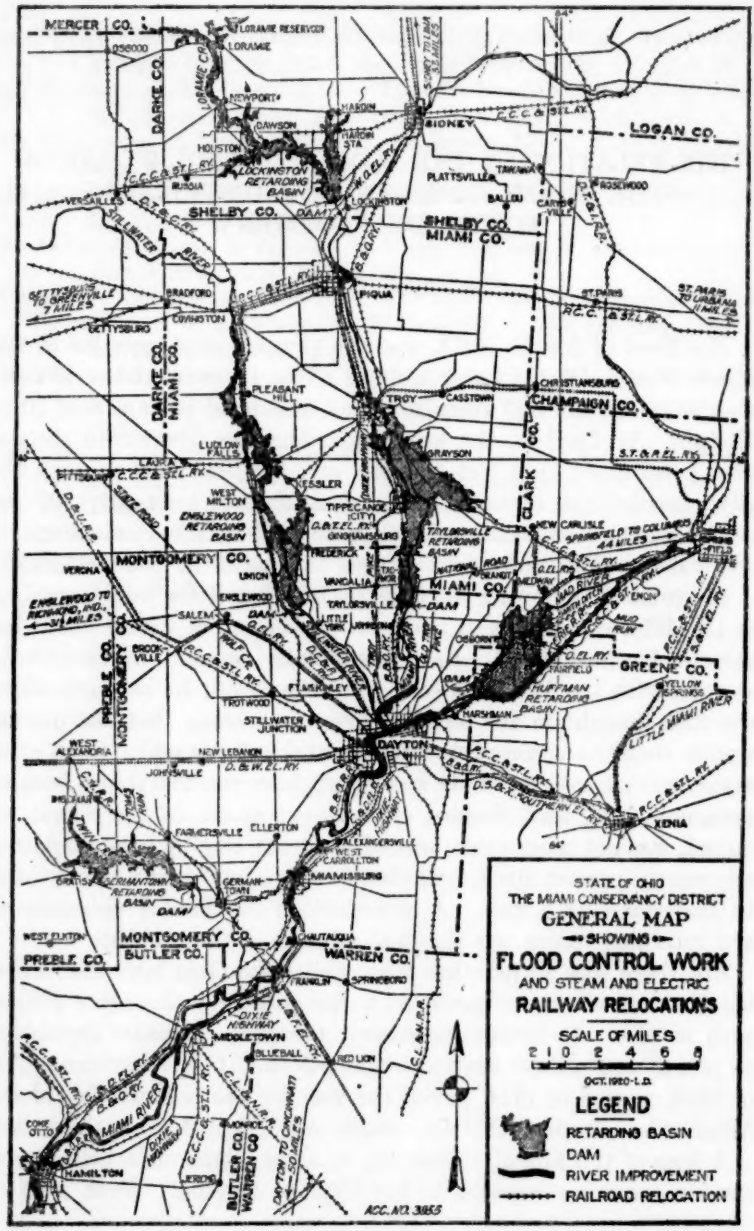

MERCER CO.
LORAMIE RESERVOIR
LORAMIE
DARKE CO.
NEWPORT
DAWSON
HOUSTON
LOCKINGTON RETARDING BASIN
LOCKINGTON DAM
SHELBY CO.
SIDNEY
LOGAN CO.
PLATTSVILLE
TAWAWA
BALLOU
ROSEWOOD
CARTERSVILLE
SHELBY CO.
MIAMI CO.
PIQUA
ST. PARIS
BRADFORD
COVINGTON
GETTYSBURG
DARKE CO.
MIAMI CO.
PLEASANT HILL
TROY
CASSTOWN
CHRISTIANSBURG
CHAMPAIGN CO.
GRAYSON
LUDLOW FALLS
LAURA
WEST MILTON
TIPPECANOE CITY
EMBLEWOOD RETARDING BASIN
TAYLORSVILLE RETARDING BASIN
NEW CARLISLE
SPRINGFIELD TO COLUMBUS 44 MILES
MONTGOMERY CO.
VERONA
UNION
FREDERICK
VANDALIA
MIAMI CO.
TAYLORSVILLE
DAM
EMBLEWOOD TO RICHMOND, IND. 31 MILES
SALEM
DAM
MAD RIVER
ENGLE
MAD RUN
GREENE CO.
FAIRFIELD
YELLOW SPRINGS
HUFFMAN RETARDING BASIN
HARSHMAN
LITTLE MIAMI RIVER
PREBLE CO.
MONTGOMERY CO.
BROOKVILLE
FT. MCKINLEY
TROTWOOD
STILLWATER JUNCTION
DAYTON
WEST ALEXANDRIA
NEW LEBANON
JOHNSVILLE
BRUBAKER
FARMERSVILLE
ELLERTON
ALEXANDERSVILLE
GERMANTOWN RETARDING BASIN
DAM
GERMANTOWN
MIAMISBURG
XENIA
WEST ELKTON
MONTGOMERY CO.
BUTLER CO.
CHAUTAUQUA
WARREN CO.
PREBLE CO.
FRANKLIN
SPRINGBORO
DIXIE HIGHWAY
MIDDLETOWN
BLUEBALL
RED LION
MIAMI RIVER
HAMILTON
BUTLER CO.
WARREN CO.
DAYTON TO CINCINNATI 50 MILES
ACC. NO. 3855
STATE OF OHIO
THE MIAMI CONSERVANCY DISTRICT
GENERAL MAP
SHOWING
FLOOD CONTROL WORK
AND STEAM AND ELECTRIC
RAILWAY RELOCATIONS
SCALE OF MILES
2 1 0 2 4 6 8
OCT. 1920-L.D.
LEGEND
RETARDING BASIN
DAM
RIVER IMPROVEMENT
RAILROAD RELOCATION

FIG. 1

east they are the Stillwater, Miami and Mad Rivers, flowing on south under the name of the Miami. Wolf Creek joins the Miami also at Dayton just below the junction of the three main tributaries. Loramie Creek flows into the Miami branch at the upper end of the valley, just above Piqua. Twin Creek joins the main river between Franklin and Middletown. Four Mile Creek comes in just above Hamilton. The drainage area above Hamilton is 3600 square miles. Above Dayton it is 2600 square miles.

As finally adopted, the Miami Conservancy plan provides for channel enlargement through all the cities and towns affected by floods, to the extent that is economically feasible, supplemented by retarding basins which will hold back the crest of the flood, by restricting the flow through the dams and backing up the surplus temporarily in the basins. The outlets through the dams are not controlled by gates, but are designed of such size that their combined discharge, under maximum head (full basin), will not overtax the capacity of the improved river channels through the cities below. The maximum flood provided for is 40 per cent greater than the 1913 flood. After an exhaustive study of rainfall and runoff records, topographic conditions, and other pertinent factors, it is believed that this maximum is in excess of any flood that may occur in this locality. Referring again to figure 1, channel enlargement is provided at Piqua, Troy, Dayton, West Carrollton, Miamisburg, Franklin, Middletown and Hamilton. Dams, forming retarding basins, are located at Lockington on Loramie Creek, at Englewood on Stillwater River, at Taylorsville on the Miami, at Huffman on Mad River, and at Germantown on Twin Creek. The cost of the work is met by special assessment against the property benefited.

It was necessary to relocate 50 miles of railroad lines throughout the valley, in order to get them out of the way of the dams and retarding basins. These included the Big Four and Erie between Dayton and Enon, the Ohio Electric between Dayton and Medway, the Baltimore and Ohio between Dayton and Tippecanoe City. New locations satisfactory to the railroad companies were made at the expense of the District, under the general directions of the railroad companies. It was necessary in every case to complete the new lines, ready for traffic, before the old lines could be abandoned. The old lines then became the property of the District, the rail and ties being salvaged for what they would bring.

Channel improvement, to a greater or less extent, is almost certain to be an economical feature of a flood control project. Even when full protection may not be secured by such means, there is usually much to be gained, at moderate expense, by removing bars and islands, and by deepening, widening, or straightening channels within reasonable limits. The cost of additional capacity increases relatively, until finally an economical limit is reached. In the Miami Conservancy project the retarding basin control has permitted channel enlargement to be confined to moderate limits through most of the cities except Hamilton, where a considerable widening of the channel, which had been severely encroached upon by the industrial plants, was unavoidable. This work at Hamilton involved considerable property damage.

Three general methods of channel improvement were required. First, that in which channel excavation is the essential or most prominent feature, as at Hamilton and Dayton; second, that in which the work is confined almost entirely to levee construction, as at West Carrollton, Miamisburg, Franklin, and Middletown; and third, a combination of these two features, as at Troy and Piqua. Cut-off channels helped the situation, also, at Troy and at Middletown. Clearing out trees and other obstructions was worth while in several places.

The standard section of improved channel at Dayton and Hamilton has a low water channel about 150 feet wide with flat slopes, or beaches, on either side, extending out to the toes of the levees. The low water channel is located in the center of the river, where the latter is straight, and near the outside of the bends where the channel is curved. Having determined upon the channel capacity obtainable at reasonable expense, the object then is to design a standard channel section which will give velocities of flow as nearly uniform as possible at any given stage, and one that will be reasonably self-maintaining. To meet these requirements it has been necessary in some cases to actually narrow up the old channel at certain points in order to prevent a decrease of velocity at such points, which would result in the formation of bars. Channel improvement in most of these cases resulted in increased velocities of flow. To prevent erosion of banks where good sod is not sufficient, concrete revetment is used at critical points.

One of the big engineering problems in connection with this project was the determination of number and size of retarding basins,

and the balancing of retarding basin capacities, outlet capacities through the dams, and improved river channel capacities through the cities. There is no time here to go into the details of this problem, which, however, has been discussed at length in one of the Technical Reports published by the District.[3] As has been said already, the final layout of the project included the construction of five dams at the locations indicated heretofore.

The principal dimensions of the five dams are as follows:

	GERMANTOWN DAM	ENGLEWOOD DAM	LOCKINGTON DAM	TAYLORSVILLE DAM	HUFFMAN DAM
Maximum height, feet	110	125	78	78	73
Length, feet	1,200	4,700	6,400	3,000	3,300
Volume eathwork, cu. yd.	800,000	3,600,000	970,000	1,130,000	1,350,000
Volume concrete work, cu. yd.	17,400	26,500	32,000	48,000	37,500
Maximum storage capacity to spillway crest, acre feet	106,000	312,000	70,000	186,000	167,000

Each of the five dams was built by the hydraulic fill method, with concrete outlet structures designed of such size as to give the required control of floods. Each dam is also provided with a concrete spillway. It is apparent that gate control of the outlets would allow a more precise control of floods, but in the Miami Valley large floods occur only at long intervals. They might be fifty or one hundred years apart. Under those circumstances it was thought unwise to depend upon gate operation. The gates might not be in operating condition when needed, through lack of use, or neglect; or the operators might fail to act intelligently at the critical time; either of which contingency might bring disastrous results. Gate control, required only once or twice in a lifetime, is not dependable. Automatic control, while not quite as economical, is much safer in such cases.

The operation of the project is simple. The ordinary flow of the river passes through the dams and on down the channel unimpeded. Small floods pass on with very little interference. Floods of moderate size are retarded somewhat by the dams but only for short periods. The large floods find themselves throttled down by the dam outlets to the extent that only a portion of the flow may pass. Just as your

[3] Technical Reports, Volume VII—Hydraulics of the Miami Flood Control Project.

wash basin, with the faucets turned on, may be filled, even with the drain plug removed, so the retarding basins, during heavy storms, become temporary reservoirs, holding back the peak of the flood, while so much of the flow as the outlets will handle passes through the dams and on down the river without overtaxing the capacities of the improved channels. As the storm subsides the basins immediately begin to empty themselves, just as the wash basin will become empty as soon as the flow through the faucets is sufficiently decreased. With a storm like that of 1913, all of the retarding basins, with one exception, would be empty, ready for another flood within seven days after the rain had ceased.

The schedule of work, as laid down at the start of the construction period, called for the completion of the last dam in June, 1923. In spite of war conditions, labor shortage, difficulties of obtaining materials, car shortage, etc., all five of the dams were near enough to completion to be ready to function in the fall of 1921, and all construction work will be finished by the end of the working season of 1922,—a full year ahead of schedule.

While the project has not yet been called upon to handle a maximum flood, the spring rains of 1922 furnished a test which gave the public its first demonstration of the efficiency of the work. On Thursday night and Friday, April 13 and 14, a heavy rainfall occurred which was general over the whole Miami drainage area. At Dayton it measured 3.11 inches, nearly all of which fell within a twenty-four period. This followed frequent rains during the five or six days just preceding, so that it fell on saturated ground, and caused a peak runoff somewhat in excess of any that had occurred since the organization of the Miami Conservancy District and the beginning of flood control work in the Valley.

With the channel improvement work nearing completion through the cities, and the dams in operation, this gave the system its first opportunity to function. Under old conditions without the flood control works, the water would have reached the old danger mark at Dayton, and would have been the cause of considerable alarm at several points along the river, particularly at Dayton, Middletown, and Hamilton. In fact there would have been a flood scare, for a few hours more of rain, under old conditions, would have been serious. As it was, the flood control works of the District were just beginning to show their value, and there was an immense capacity still available within the river channels and in the retarding basins.

The maximum depth of water stored in each of the retarding basins was as follows:

	feet
Germantown	40
Englewood	37
Lockington	21
Taylorsville	20
Huffman	18

A total of approximately 36,000 acre feet of water was held back. While this was insignificant compared with the total capacity of the basins, it was enough to make a good showing, and at Englewood and Germantown particularly it was viewed with great interest by many thousands of people. At both these places excellent examples were given of the actual working of retarding basin control. During the early stages of the flood the water passed on through the outlets unimpeded. As the flood increased the limit of free flow through the outlets was reached and water slowly backed up in the basins. This first occurred at Germantown and Englewood, where the outlets are smaller than at the other dams, compared with the size of the streams. As the water backed up in the basins the discharge through the outlets increased slowly, and the action of the hydraulic jump came into notice as it cut down the high velocity of the water within the limits of the stilling pool. At both Germantown and Englewood velocities as high as 25 to 30 feet per second were reduced, by means of the hydraulic jump, to 5 or 6 feet per second.

Everything worked out at the dams exactly as was expected. The things which made the most impression on the general public were, the visual evidence of actual storage back of the dams; the immense amount of storage capacity still available in the basins; the marked effect of the hydraulic jump, or stilling pool, reducing the high velocities at the conduit outlets, and the comparatively low stage of the rivers through the cities.

While it was apparent that this flood was small compared with the maximum that the project was designed to handle, it was still a clear demonstration of the effectiveness of the works, and the people of the Miami Valley then realized that flood danger, for them, was a thing of the past.

From this brief description of the Miami flood control project it will be seen that it has no effect whatever on water supply or power development. The design of the works is such that no combination

with water supply or power projects is feasible. No permanent storage is provided at any of the retarding basins, their full capacity being held available for flood control. As far as a combination with power development is concerned, there are several reasons why that is not feasible. First, the low water flow of the Miami River is small, and long period storage to augment the flow during the low water reason is not practicable in combination with the retarding basins. Flood control requirements demand that the basins remain empty except when called upon to hold back surplus flood waters. There is not room in the basins for flood control capacity on top of storage for power purposes. Second, fall could be provided only by backing up the water at the dams and that, again, would reduce the available flood control capacity. Third, the lands within the basins are now available for farming and are so used, it having been necessary only to relocate the buildings on high ground. Some of the best crops in the valley are raised within the limits of the retarding basins. The big floods, when they do occur, almost always come in the spring, before the crop season, and instead of damaging the crops, they leave a deposit of silt which is valuable as a fertilizer. Such lands are too valuable to be flooded for the sake of the small amount of water power that might be obtained thereby.

As for water supply, the cities in the valley are otherwise provided for, and as yet there has been no reason to consider water supply storage in this connection. Had such a demand arisen, the same objections would have applied as have been mentioned. There is a further objection to any combination of this sort. Water supply or power storage, once established is required constantly. The demand is continuous and evident, and increases as the communities grow. Flood control requirements are much less evident to the general public, especially in a locality where maximum floods may occur only once or twice in a lifetime. There is grave danger in such cases that, in a combination scheme, the flood control requirements would be sacrificed to the more insistent demands of the other, with the result that eventually the original flood protection might be seriously reduced. One of the big problems in the Miami Valley today is to keep alive in the public mind the necessity of maintaining the flood control works at 100 per cent efficiency, ready for the supreme test when it comes. That test may not come for a century, it may come tomorrow, it surely will come some day. When it does come, the value of complete protection, with original capacities unimpaired, will be fully realized.

VALUATION AND RATES[1]

By Chester H. Loveland[2]

It is obvious that the most important element in the success of a water utility, whether owned by a governmental agency or by a private corporation or person, is the rates which that utility may charge for the service rendered by it, and a very important element in the establishment of the rate schedule is the value of the property used in rendering that service.

Many books have been written upon each of the subjects assigned to me for discussion, so it is presumed that the Chairman expected me to discuss only those features which might well be termed the high lights, or more salient phases.

During a period of seven years I did little else than study the principles involved in and watch the application of valuation and rates in water utilities throughout the state. During that period every phase of valuation and rate making for water utilities was in one manner or another brought to my attention. I have watched the details from the standpoint of the engineering features and have studied the theory and practice of various courts and commissions.

In this discussion I shall try to bring before you some of the outstanding principles and my personal views regarding them.

Inasmuch as this is a convention of water-works men, I want to handle these subjects as nearly as possible from a water-works point of view. While the general principles involved are the same, the application of those principles and the detail necessarily are different for different classes of utility service. And when I speak of a "utility" in this connection, it is intended to include not only those quasi-public-service corporations which are privately owned and which we know as public utilities, but also municipally owned utilities, for no matter where the ownership lies, the same questions have to be dealt with in the establishment of rates, the outstanding difference between the so-called public utilities and other utilities

[1] Presented before the California Section meeting, October 27, 1922.

[2] Consulting Engineer, Oakland, California.

being that the former are under the jurisdiction of the Railroad Commission, in this state, while the others are not.

Investment in water works systems. When one stops to consider the investment in domestic water supply systems in this state, one can well realize the importance of this question of rates. At the present time approximately 300 million dollars are invested in water systems in California. In the next ten years, a conservative estimate places the money that will be expended for new systems and for replacement, extension and enlargement of existing systems at a minimum of 150 million dollars.

Importance of service. Viewed from another angle, the health and welfare of the State are largely dependent upon the quality and quantity of its domestic water supply. As a matter of fact, *service* should be placed first in importance. In order to render good service, however, a utility must be financially sound. It has been my observation that financially poor utilities and poor service go hand in hand.

I may say that, as a whole, throughout California, exceptionally good service is being rendered by the present agencies. These agencies, in large part, have been under the jurisdiction of the California Railroad Commission. While the companies have been kept as nearly as possible in good financial condition, the consumers have been protected, both in service rendered and rates charged.

Cost of service. In the process of producing, transmitting and delivering water to consumers, the agency that sells the water must be compensated for the expense incurred. Inasmuch as this service is either rendered by a utility which is regulated by the State or owned by governmental agency, and is, in fact, a monopoly, the ordinary law of supply and demand which governs in the fixing of prices of many other commodities, cannot apply. That is to say, the utility is permitted to operate as a monopoly and is protected against competition; on the other hand, to insure that the monopoly may not exact exorbitant prices for a commodity which is an absolute necessity of life, the rates charged for service are regulated and determined, as nearly as may be, upon the basis of the cost of service, such cost including an interest return, and being fixed by a governmental agency by means of regulation or ownership. Let us analyze, then, the elements which go to make up the cost of service, which, because of the fact that the various costs are ordinarily determined upon a yearly basis, are more commonly referred to as the *annual charges*. The annual charges include an interest return upon the

value of the property used in rendering the service, the necessary expenditures for the operation and maintenance of the plant, and a sum sufficient to amortize the cost or replace the plant at such time as it has become fully depreciated or worn out, in rendering service to the water users. Ordinarily the rate schedule established is designed to yield the sum of these elements, provided, however,that the sum so arrived at will not necessitate a rate schedule which would make the cost to the various consumers greater than the value of the service rendered to them. In other words, consideration must not only be given to the cost of service to the utility, but also to the value of the service rendered to the consumers.

Valuation. In determining the interest return, it is necessary to establish the value of the plant used in rendering service, and by so doing arrive at an amount upon which an interest return shall be computed. Valuation is one of the most discussed and contested elements entering into rate fixing.

It may be well at this point to define "value." Various definitions have been given by economists, but the simplest and, perhaps, the most comprehensive is that "*Value is use, expressed in terms of dollars.*" It is apparent that this definition entirely eliminates the element of cost. Further, it is apparent that unless cost is commensurate with value, the commodity would not be developed. In the case of regulated monopolies, however, such as a water system, the cost of the plant expressed in one form or another has come to mean value, in those instances where all of the plant is reasonably used and useful in rendering service, and where service is rendered within a reasonable margin of the capacity of the plant.

Value vs. cost. A common fallacy has crept into the terminology of regulation; that is, the use of the word "value" as synonymous with "cost." Obviously the value of a thing may be far different from its cost. For instance, a mile of pipe-line may be required to serve one consumer in a locality where there is little probability of serving additional consumers. This line may have cost $2,000, yet its value may be only a small percentage of this cost, due to the fact that it may never be expected to yield a fair interest return upon its actual cost.

Methods of estimating. In appraising the facilities of a utility for the purpose of determining value, four different methods are in common use. These are on the basis of (1) actual investment, (2) estimated actual investment or estimated historical cost, (3) repro-

duction cost based upon prices of material and labor as of the date the rate fixing was initiated, and (4) reproduction cost based upon prices of materials and labor averaged over a period directly preceding the date on which the rate proceeding was filed, sufficient in length to construct the plant. A fifth method is frequently presented, which is an estimate based upon prices of materials and labor averaged over the period of from five to ten years prior to the abnormal rise of prices occasioned by the war.

Often there is included in the sum upon which the interest return is computed, not only the cost of the physical properties, but also an allowance for working capital, the value of water rights, going concern, etc., particularly in those instances where it can be shown that an actual expense was incurred by the utility.

Working capital. It is comparatively easy to estimate, with a reasonable degree of accuracy, the cost of the various physical properties of a company. In regard to the other more or less intangible elements, no definite satisfactory method has been devised. For example, in *working capital,* which is supposed to be the amount necessary for the company to have on hand in order to meet its current obligations until such time as it has received from earnings a sum sufficient to meet them, a more or less rule-of-thumb method has been adopted, which is the establishment of an amount as working capital equal to two months operating expenses. Some Commissions have reduced this to from 25 to 40 days in instances where the utility is collecting in advance for the service rendered by it. Various other methods have been used and elaborate analyses have been attempted.

Water rights. Although it is clearly established by the United States Supreme Court that water rights have a value, no method has yet been accepted as final in its determination. Clearly the value cannot be based upon income produced from the sale of water, because if this were done in a rate proceeding, it would be merely traveling in a circle—that is, rates based on value and value based on rates.

Although no method is universally accepted, the same underlying elements govern in each case, which, in fact, goes back to the fundamental definition of value—Use expressed in terms of dollars.

Among the many methods used by engineers, courts and commissions, in arriving at the value of water rights, there have been used as a basis: (1) the actual cost of the water rights in question, (2) the estimated market value measured by sales of other water

rights, (3) the estimated cost of the next available source of supply, and (4), the estimated value of the rights based upon the improvement made possible by the use of water.

Going concern value. The subject of going-concern value is in much the same category as water rights. It has been defined as the *value of an active operating business* as compared with the value of the "bare bones" of the plant. Two phases of it are usually analyzed, the one being the development of the "bare bones" of the plant into a system capable of efficient and economic operation, the other being the value which may accrue due to the plant being an operating, active business, having consumers for its commodity.

In regard to the first phase, it might well be that a utility would be put to a considerable expense in developing the operating efficiency of its plant. For example, money might be expended to construct a dam or sink a well which would not be productive or of use as planned, yet the expenditure may have been made upon the advice of the best engineering talent available and with the exercise of good judgment at the time it was planned. Such expenditures in fairness should be included as a part of the value of the plant. Many methods have been devised of estimating this value, principal among which is the method of capitalizing deficits over a reasonable development period.

I do not wish to seem to hedge, but, because I have omitted so many important phases of this subject, I wish to emphasize that this is only a general statement of a subject upon which volumes have been written and in which, in specific instances, other elements may enter which are largely determinative as to what amount, if any, shall be added to the value of the physical plant for going concern.

Undepreciated cost used. It has become more or less common practice among courts and commissions to use the undepreciated value as what may be termed a rate base upon which to compute the interest return. This method was originated because the utility is compelled to replace its plant and keep it in an efficient operating condition. Based upon this supposition, therefore, the utility, or rather the investors in the utility, are not at any time permitted to withdraw any of their investment from the plant, and, in fairness, they should be permitted to earn an interest return upon it. It is readily apparent that this may differ from the value of the plant if we again consider the fundamental definition of value, for by so doing it is clear that the value is the use remaining in the plant expressed in terms of dollars, which is a depreciated base.

Cost of money. After the sum has been determined upon as the value of the plant upon which interest shall be computed, it is necessary to determine what rate of interest shall be used as a fair return. The cost of money at the time of the proceeding determines more or less this rate of interest. It may be said that it has been indicated in some court decisions that a rate in excess of 6 per cent was not confiscatory, yet clearly there is a considerable margin between what may be a confiscatory rate and what may be a fair interest return. Eight per cent has been commonly adopted in normal cases, and particularly in California, as is evidenced by the decisions of the California Commission. In the case of a governmentally owned utility, the interest is ordinarily the amount necessary to pay the interest upon the bonds issued for the purpose of constructing the plant.

Explanation of allowance set aside for replacement reserve. It is obvious that, when a system is utilized in delivering water, the wear and tear upon the system and its deterioration is an actual cost to the utility for the benefit of the consumer, and as such should be included in the annual charges. In all rate proceedings a replacement annuity is computed, based upon the value of the property used and useful in the service of the public. This replacement annuity is designed to yield a sufficient sum so that the property may be replaced at the end of its useful life.

Maintenance and operation. In addition to the interest return and the amount which is included for the amortization of the cost of the plant or its replacement, another element enters the cost of service, which is the cost of maintenance and operation, including taxes. In some instances commissions and courts have segregated maintenance from operation, and have also considered taxes as an independent item. For the purposes of this discussion they have been considered as one.

Normal operating expenses govern. In the determination of proper operating expenses to be included in the cost of service, it has been assumed by many that the expenses incurred during the previous year should almost, if not entirely, govern. It is pointed out, however, that these expenses may in many instances be lower or higher than an average for a series of years and may not be a true criterion of the expenditures reasonably necessary. In other words, the reasonable normal expenditures necessary to maintain and operate the system are the governing factors, and may be segregated as between:

1. Expenses recurring annually.
2. Those expenses recurring at periods longer than one year.
3. Extraordinary expenses—such as may be caused by floods, fires, etc.

Expenses recurring annually. Under the first heading fall the ordinary maintenance and operating expenses which occur regularly and in approximately like amounts from year to year, consideration, of course, being given to the conditions existing at the time of the rate establishment. For example, in general administration, it may have required the time of one, two or three men for a number of years. Yet the salary of one or all of them may have been increased during the year directly preceding the rate establishment. This phase might well be described as the cost, as of the time of the rate establishment, of performing functions which are and have been necessary over a long period of time.

Expenses recurring at longer periods. In the second class of expenditures there falls the cost of such items as the thorough overhauling of pumps, cleaning of wells, etc., which may be required only in periods of from two to five years or longer. In this class of expenditures, a reasonable cost is estimated and also the period of their probable recurrence. The total cost is then spread over the period.

Extraordinary expenses. In the last classification, that of extraordinary expenses, an allowance is ordinarily included which is designed to amortize these emergency expenditures over a reasonable period. For example, a fire may occur which would necessitate the expenditure of a considerable sum of money in repairing equipment. This cost should be amortized, inasmuch as it is necessary in rendering service, and yet it is impossible to definitely estimate how often such an emergency would arise.

Maintenance or capital investment. The question often arises as to where maintenance stops and capital investment begins. In fact there is no clear line of demarcation between expenditures for the maintenance of plant and replacement or improvement of plant. It may be said, generally speaking, that, wherever the expenditure is necessitated for the maintenance or replacement of a unit of plant which is a distinct entity in the plant as a whole, the expenditure is one properly chargeable to capital and that, in those instances where the expenditure is necessary for the maintenance of a comparatively small portion of a unit of plant, the item should be charged to maintenance.

Summation of annual charges. The summation of these three elements, that is, the interest upon the fair value of the plant, the replacement reserve and the maintenance and operation expenses, including taxes, is the amount which the utility is entitled to receive as revenue, provided, of course, a rate schedule designed to yield this sum will not require the payment by the consumers of an amount greater than the value of the service rendered to them, or more than the traffic will bear.

Spread of rates. Having arrived at the total sum that the utility is entitled to earn, there remains to be established a rate schedule which will yield this sum. The rate schedule should be of such form that each consumer, as nearly as possible, pays his fair share of the total expense of service. If he pays more than his fair share, some other consumer is paying less for the service received by him than he should, and vice versa.

It is immaterial to the utility how the total charge is spread among the consumers, as long as it receives the total sum to which it is entitled, *except* that the utility in its dealings with its consumers, in other words, in its public relations, is interested in not having any consumer pay more than his fair share.

Beneficiaries of service. Each consumer should pay in proportion to the benefits derived. Who are the beneficiaries of a water service? Benefits derived from the existence of a water system inure to two different classes, (1) the water user, and (2), the property owner within the area served. In many instances these two classes are identical. The water user is benefited by the actual use of water and having it available for use. The property owner is benefited in increased value of property, whether that property be vacant lots or improved property, in fire protection, sanitary facilities, beautification, cleanliness of the city, and in the availability of water service.

Allocation of charges. In view of these benefits derived by each class, an allocation of the charges should be made so that each pays his share in proportion to the benefits derived. There is no available measure for determining the exact value of each of these benefits in terms of dollars. Municipalities owning their own water works have attempted to allocate these charges by including in the general tax a material portion of the total annual charges for water service.

In rate schedules of public utilities, courts and commissions have attempted to allocate these charges. It is apparent that, if the

owner of a vacant lot says that he does not desire service, no charge can be levied against him by the privately owned water utility. On the other hand, if a portion of these charges is included in his taxes, he can not escape paying it. Some cities have included as high as 50 per cent of their entire cost of service in taxes, and the balance is collected as a direct charge for water.

Fire service. One of the benefits accruing to the property owner is fire service, which ordinarily is paid for by the municipal government. This is a direct service rendered by the water company and desired by those receiving it, and therefore a charge for it may be assessed. Regulatory bodies have attempted to apportion properly this expense and have used various methods, all of which are, and must be, approximations, because of the nature of the service. In other words, it is impossible to estimate the proper proportion of the total cost of service which should be allocated for fire service.

In rendering municipal service for fire fighting or other purposes, a utility must have a system of sufficient capacity, adequate pressure upon its mains and must hold itself ready at any moment to concentrate a large quantity of water at any given point on its system. Obviously it is difficult so to apportion the total charges that this service, (which is essentially a stand-by service), shall return to the utility its fair share of the costs.

Service of these same general characteristics is also rendered to large commercial and industrial establishments who have installed extensive automatic sprinkler systems and hydrants for fire protection.

METHODS OF ALLOCATING EXPENSE TO FIRE SERVICE

Surplus capacity method. One method of allocating this expense is known as the "*surplus capacity*" method, in which an estimate is prepared of the cost of a system having only sufficient capacity to serve the consumers who have been termed herein the water users, and this sum is deducted from the actual cost of the system, in an attempt to arrive at the value of that portion of the system used in rendering the so-called municipal or fire service.

Comparative plant method. Another method is to prepare an estimate of the cost of a system necessary to serve the water users and also an estimate of the cost of a system necessary to render the municipal or fire service. By applying the proportion that each is to the sum of the two to the cost of the system as it exists, we arrive

at the proportion of the total cost to be borne by each class. This is known as the *comparative-plant* method. A further estimate is then prepared of what proportion of the maintenance and operation and other necessary expenses should be allocated to each class of service.

Percentage allocated to fire. Utility commissions throughout the United States have by the use of one or both of these methods, and, as a matter of fact, often times by the pure exercise of their judgment as to what is reasonable, established charges ranging from 10 to 50 per cent of the total annual charges. Usually, in those cases where an attempt has been made to arrive at a proper allocation, the charges range from 25 to 50 per cent of the total of the cost of service. By these means, then, it is attempted to distribute among the class of beneficiaries, the property owners, that proportion of the total annual charges which should rightfully be borne by them.

Distribution of charges among water users. The next step is to apportion equitably the remainder of the costs among the domestic, commercial, industrial and other water users. The charges for this service may be divided into two classes: one, a service or capacity charge, and the other, a quantity charge.

The practice has grown up among those bodies establishing rate schedules, to establish a *service charge* or a *minimum bill*, the only difference between the two being that the minimum bill is higher and has concealed within it both the service charge and the quantity charge for a certain minimum quantity of water, usually ranging from 400 to 800 cubic feet, while the service charge does not include payment for any quantity of water. Obviously, it is unfair to require of a consumer using 200 cubic feet that he pay for perhaps twice the quantity he desires to use.

Service vs. quantity charge. The allocation between the service and the quantity charge is usually made in a more or less arbitrary manner,—the *service charge* including the interest, depreciation, maintenance and operation upon those facilities that serve the individual consumer, and the *quantity charge*, the cost of the production, transmission and distribution of the water through those facilities that are used for the benefit of the consumers as a whole.

Graduated service charge. The amount of the service charge usually varies with the size of the service connection and meter; that is, the larger the facilities for individual service the higher the service charge. The quantity charge varies with the quantity of water used, inas-

much as what we know as a *block schedule* of rates is ordinarily established wherein the charge per unit of water decreases as the use becomes greater.

Block schedule of rates. Much discussion has arisen relative to what reduction in cost should be allowed per unit of quantity for large users over small users. This largely becomes a matter of expediency. It is a wise business policy and tends to reduce the payment by the small consumers if a graduated schedule of rates is put into effect which will induce large users to increase their consumption.

Recently I noted in the news items an instance where a city, through the acquisition of its distribution system and the purchase of electricity at wholesale rates, was enabled to operate at a less total expense to the ultimate consumer than obtained at the time when its citizens were paying for the service at the rates for small users. Although the rate for wholesale quantities under this schedule undoubtedly lessened the unit rate for small users beyond which would have obtained if no inducements had existed for the use of power, still, this wholesale rate, of necessity, does not cover the total cost of production and delivery. As a matter of fact, if these wholesale rates covered all the costs of production, transmission and delivery to the point of use, at the central point of service, there would be no occasion for the higher rates for small use or for a different class of use. In other words, if all the consumers of this company were receiving service under a wholesale rate schedule, that schedule would be much higher than the one that now obtains. Therefore, it is not fair to compare the results obtained under this schedule with the rates in other communities under the same system.

REPORT OF STANDARDIZATION COUNCIL

During the past year, progress reports have been made to the Standardization Council by the several committees functioning under it, and from this material reports have now been printed in the JOURNAL, as follows:

Committee 14. Slides in Meter Schedules; July, 1922.
Committee 8. Physical Standards for Distribution Systems; January, 1923.
Committee 4. Colloidal Chemistry in Relation to water Purification; March, 1923.
Committee 3. Practicable Loadings for Water Purification Processes; May, 1923.
Committee 5. Watershed Protection; May, 1923.
Committee 6. Industrial Wastes in Relation to Water Supply; May, 1923.
Committee 8. Second Progress Report on Physical Standards for Distribution Systems; May, 1923.
Committee 13. Methods and Records for Water Waste Control; May, 1923.
Committee 16. Essential Data for Water Works Records and Reports; May, 1923.

Council believes that its committees are entitled to much credit for the work they have done, and that the general movement toward standardization of water works practice is progressing along safe and helpful lines.

In addition to the reports already printed, information has been secured which could be worked up in other similar reports. But it is deemed wisest to restrict the number of reports at this time to those now before the Association, in order that there shall be ample opportunity for discussing them at length at the Detroit convention. It is usually possible to obtain a greater interchange of views in such discussions than is feasible by correspondence. In brief, Council is more desirous at this time of having subject matter discussed which has already been put before the Association than to prepare more material for the general consideration of the membership.

As progress is made towards a coördination of views and the standardization of water works practice, it is the present belief of Council that standardization reports of a comprehensive character, of much benefit to water works superintendents and to the public

alike, may be published. When this goal is attained, there will be no room for doubt about the Association accomplishing the main purpose sought in the establishing of this standardization program.

It is with much satisfaction, therefore, that Council learns that the Publication Committee and the Program Committee have taken steps to promote group meetings dealing with some of the practical questions of interest to plant operators. As the number of these group meetings increases and the views of the superintendents resulting from them take more definite form, it is hoped that the information gathered together from the discussion of Question Box and similar topics may assume such proportions as to make it desirable to have more committees appointed which will standardize practice along lines of particular interest to superintendents.

The committees of Council having to do with water analyses and water standards are waiting for the results of the work of the Advisory Committee on Official Water Standards appointed by the U. S. Public Health Service on May 15, 1922. It is hoped, however, that on these matters a progress report can be made at the Detroit convention.

Council has presented in somewhat condensed form during the past year the material furnished by certain committees. This abridgement has been necessary because of the limitations of space available in the JOURNAL and of the funds allotted for printing. But it is believed that no great sacrifice has been made by the terser statements characterizing the printed reports of committees of Council as compared with more detailed papers and reports so often published in this country heretofore.

The abstractors prepared about 83 printed pages of information about useful papers and reports during 1922. It has been found that a much larger volume of such information useful to the members may be obtained readily. The cost of publishing such an additional number of abstracts must be considered by the Association's Executive Committee during the Detroit convention.

Council has had the benefit of different views expressed by members regarding its activities, and it expresses its deep obligation to all who have furnished suggestions about its work. Some members believe more abstracts should be published, because a large proportion of the members of the Association do not see regularly many publications containing information relating to water supply. Others go farther and advise, also, asking the chairman of each committee

having a report up for discussion at a convention to arrange with at least two members present at the convention to lead the discussion. Those who have followed the standardization program from its inception wish the undertaking to progress at a rate which, for a few years, will probably require, for printing more information in the JOURNAL, some of the funds which the Association has saved in recent years. There is now about $12,000 invested in United States and Canadian government bonds. The opinion of these members is that if new members are to be obtained, with a corresponding increase in the annual income from dues, it can only be, speaking broadly, through publication of information demonstrating clearly that the American Water Works Association holds the leadership in everything relating to water supply. On the other hand, some members believe that the Association should live strictly within its current income, which means that there shall be no increase in the present volume of abstracts and no space for detailed discussions in the JOURNAL of the reports of committees, unless the papers by individuals printed in the JOURNAL are curtailed and the program of standardization is slowed down from the rate at which it has heretofore been carried on.

Council requests that the members of the Association go to Detroit prepared to discuss these divergent policies, so intimately associated with the work of Council, the advancement of the Association, and the financial affairs of the organization.

The personnel of Council during the third year of service has been as follows: Chairman, George W. Fuller, New York; George A. Johnson, New York; Frank A. Barbour, Boston; Edward Bartow, Iowa City; George C. Whipple, Cambridge, and Malcolm Pirnie, Secretary, New York. While it is essential to maintain a continuity of policy, Council believes that its work of standardization is now so firmly established that it is desirable to change its present personnel, and it is proposed during the coming year to replace one or perhaps two members with new men.

It is expected that during the Detroit convention a number of changes will be made in the personnel of the committees of Council, in order to replace with new men those who have been unable, for any cause, to proceed actively in committee work. At the close of the convention, Council will submit a revised list of the members of its committees.

PROGRESS REPORT OF COMMITTEE ON WATERSHED PROTECTION[1]

Watershed protection is viewed quite differently in the several sections of the country owing to the striking variations in local conditions, such as size of watershed, extent to which the watersheds are exposed to transient and permanent population, physical condition of the watershed, extent to which the supply is impounded and particularly as to whether or not purification is used. It became quickly apparent, in order to bring coördination of viewpoints and to set forth topics on which discussion might be advantageously held, that it is essential to call attention at the outset to different types of watersheds from which public supplies are derived. We point out four main types as follows:

1. Relatively large watersheds where conditions are such as to require filtration.

2. Very small watersheds, uninhabited and controlled by the waterworks authorities and where there is little or no storage in impounding reservoirs.

3. Watersheds with storage reservoirs large enough to hold the average runoff of many months or a year or more.

4. The intermediate type of watershed, relatively small, exposed to pollution, where filtration is not adopted and where geological and other conditions are such that a moderately satisfactory water supply is procurable in the absence of filtration, provided that the protection of the watershed is given due care.

[1] This report has been prepared under the direction of Council to present again some features of the preliminary report made by this committee at the Philadelphia Convention, May 1922. Particular attention has been given to presenting material on topics susceptible to discussion, with a view to securing an interchange of ideas at the convention among those particularly interested in this subject. The personnel of this Committee has been as follows:

Theodore DeL. Coffin, Chairman, Katonah, N. Y.; William W. Locke, Boston, Mass.; Reeves J. Newsom, Lynn, Mass.; Fred M. Randlett, Portland, Oregon; S. P. Senior, Bridgeport, Conn.; W. L. Stevenson, Harrisburg, Pa.

As this report goes to press, Council regrets the resignation of Mr. Coffin, who has been succeeded as Chairman by Mr. Stevenson.

It is recognized that the filtration of surface supplies is an important feature for the vast majority of American water supplies, if for no other reason than to secure clean water for domestic use. However, there are many exceptions to the general rule in an important list of well-known water supplies, including those of some of the largest metropolitan districts in this country. Just where to draw the line between water supplies which need not be filtered and those which should be filtered is an academic question for the members of this Association resident in a majority of states and sections of the country. Although a great deal is known about certain water supplies in the northerly states, where filters have not been adopted, it is thought prudent for this committee to leave out of its reports and discussions for a while the question of just where to draw the line concerning the characteristics of a water supply which needs filtration as distinguished from one that may be made moderately satisfactory without filtration. This subject will be taken up at a later date and it is expected that aid will be received in the meantime from Committees Nos. 2 and 3, dealing respectively with Standards for Satisfactory Drinking Water and Practicable Loadings for Purification Processes.

In this present report, attention is particularly directed to that intermediate type of watershed mentioned above as Type 4, on which there are many topics which may be advantageously discussed by the members of the Association, as follows:

1. Ownership of watershed.
2. Physical character of watersheds and water courses.
3. Data on water-borne diseases.
4. Elimination of nuisances.
5. The laboratory as an aid in watershed protection.
6. Needed legislation to provide authority for watershed protection.
7. Means of enforcing needed regulations.

We will outline briefly prevailing views on each of the foregoing topics, paying particular attention to points upon which there is unanimity of opinion and also noting those where there are variations in prevailing practices and viewpoints. On these subjects the committee greatly desires to secure the benefit of views of members of the Association, particularly where such views are based upon practical experiences.

OWNERSHIP OF WATERSHEDS

The purchase of much or all of the land on the intermediate type of watershed is seldom negotiable. Even where this step has been taken it does not afford protection against trespass, except in rare circumstances where the area is isolated or where patrol is unusually effective. It must be remembered that over-confidence on the part of water users may exist because they do not realize that the occasional trespasser or careless patrolman may bring about pollution thought to be impossible.

On the basis of specific merit, this question of purchase of watershed becomes essentially one of whether the investment is worth while. This in turn depends largely upon whether or not the area may be maintained in a much more sanitary condition if owned by the waterworks authorities, than would be possible if the area were privately owned. Generally speaking, purchase of the land of a watershed is not worth while, except in instances where the land is very cheap or where it is highly important to eliminate objectionable conditions which cannot otherwise be brought under control.

Experience in handling watersheds shows that ownership of land becomes less and less practicable as the size of the watershed increases. Investments in land have been found to approach the cost of investments in large storage reservoirs or more particularly in filter plants, and the protection from the latter is greater than that derived from attempts to depopulate many watersheds. Furthermore, it is only a question of time when the vast majority of all surface water supplies will require filtration in order to secure a water of satisfactory appearance and reliable hygienic quality at all times. When filters are adopted, land purchases are not as a rule found to be good investments and money so applied might better have been put into a fund and allowed to accumulate for meeting the expense of filtration.

This general viewpoint is not without its exceptions which apply more particularly to the small watersheds and to the economic aspects of whether efficient protection of the catchment area may be assured by land purchase to an extent sufficient to justify such a step. When the step has been taken, its effectiveness is continually dependent upon the program of watershed control, which involves both the enactment of adequate laws and the efficacy with which the laws are enforced.

Marginal strips about reservoirs are sometimes purchased in inhabited watersheds to prevent easy access to the shores or to allow the most advantageous relocation of roads. They are of doubtful value as a means of reducing pollution in the majority of cases and sometimes serve to instill in the minds of the water consumers a false idea of security.

PHYSICAL CHARACTER OF WATERSHEDS AND WATER COURSES

The contour, geological formation, shape and location of a watershed have considerable bearing upon the effectiveness of the various methods of watershed protection. Precipitous, rocky areas unsuited to cultivation often give opportunity for protection by land purchase. The majority of watersheds include flat valleys and gentle slopes suited to cultivation so that the land is valuable in proportion to its nearness to a center of population. Land purchase is prohibitive and the wastes from the inhabitants of the watershed must be cared for in the most effective manner. In these circumstances, the geological formation of the area, together with the absence of existence of freezing conditions during part of the year are factors in determining the extent of natural purification of the polluting materials.

Porous sandy soils of considerable depth act as filters for polluted wastes entering them. In northern climates they may be robbed of their usefulness in winter by the freezing and ice coating of the surface, so that filth discharged on the ground may be washed long distances into streams, but where freezing temperatures are infrequent and of short duration, the water from a sandy area may be kept free from gross pollution. Exceptions are found where the sandy covering is thin and the underlying material is seamy or porous rock or coarse gravel.

Where the surface soil is impervious, filth deposited on the surface either directly or by overflowing receivers will find its way into water courses to a certain extent at all times and in great concentrations during heavy rains. If seamy rock or coarse gravel layers exist close to the surface, wastes from privies and cesspools entering them directly will flow rapidly with little purification underground to the stream courses.

Enough has been outlined above to demonstrate the inadvisability of formulating general rules for watershed protection for all watersheds. While leaching cesspools and privies are efficient means of disposal in deep sandy areas, they will overflow in impervious soils

and will directly pollute streams where access is obtained to seams in rock or large voids in gravel. Such a general set of rules might be needlessly stringent for one area and hopelessly inadequate for another.

DATA ON WATER-BORNE DISEASES

The early detection of water-borne diseases on a watershed is an important duty of the watershed police. Immediate steps should then be taken to secure safe disposal of all wastes from the house sheltering a patient, and vigilance should be exercised to see that the special sanitary precautions are carried out until all traces of the disease have disappeared. The history of each case should be recorded with evidence as to source of infection and if other inhabitants of the watershed were known to have been exposed to the suspected source their health should be reported daily until the expiration of the maximum incubation period (about three weeks) and steps should be taken to compel their use of facilities provided for safe disposal of excreta and urine.

The relatively long period of incubation of typhoid fever and the persistence of the bacteria in the discharges after convalescence, together with the development of occasional carriers, are factors which limit the effectiveness of attempts to check the spread of infection. The most that can be done along these lines is at best no more than half way protection, but even this is well worth all that it costs for all unfiltered surface supplies.

ELIMINATION OF NUISANCES

For isolated residences or small communities in seamy rock formations, watertight privy vaults of approved design should be used. The soil should be removed regularly to a safe point for burial or deposition on the land. Sewage in chemical tanks or equivalent appliances should be disposed of in a similar manner. Water carried sewerage should be prohibited as far as possible and, if allowed, the sewage should be purified to the highest possible degree before being discharged into a stream. Sedimentation tanks followed by intermittent filtration and chlorination have proved effective.

If the soil is sandy and deep, leaching privies properly protected against surface wash may be allowed in locations reasonably remote from water courses. Septic tanks with subsurface irrigation or

cesspools may be employed in approved locations for disposing of water carried sewage from isolated residences and broad irrigation on suitable land may be used for sewage from small communities or institutions.

When all things are done that can be done to minimize pollution from isolated residences and communities, there still remains the pollution from casual frequenters of the watershed traversing it on foot, in trains or by automobile on the highways. No measures now in force are thorough in preventing pollution from such sources, although intensive educational campaigns supplemented with frequent signs to notify strangers that they are on the watershed of a public supply may tend to reduce it. The locking of toilets on trains crossing some watersheds greatly reduces the danger from them, but this measure cannot be enforced at all times.

Proper disposal of garbage, the elimination of leachings into streams from manure piles and barn yards and the purification of wastes from creameries, cheese factories or other industrial enterprises on a watershed are important in safeguarding the purity of the water supply. Disposal of garbage should be of such character as to prevent it from being thrown into water courses or placed upon the ground in such a way that it may be washed into them by heavy rains. Manure piles should be placed where leachings from them will soak into the ground, thus conserving their value as fertilizer and preventing the pollution of the stream. Disposal plants should be installed to clean up the wastes from industrial enterprises on the watershed. These wastes will be dealt with in detail by Committee no. 6, on Industrial Wastes in Relation to Water Supply.

Where the amount of sewage is considerable, it should be carried to a central disposal point where works should be built and operated to produce adequate purification. Where the physical character of the ground is such that leachings from privies and cesspools would find their way rapidly into stream courses, it is sometimes advisable to sewer completely a small community, furnish it with a water supply and to carry the sewage to a central disposal plant of this character.

In attempting to eliminate nuisances on a watershed, all of the money available for this purpose should be spent first in removing gross pollution. It would avail little to build and maintain signs designed to prevent pollution from individuals traversing the area, while the discharge of raw sewage from a community into the supply

were allowed to continue. The effectiveness of watershed protection depends largely upon the ability of the authorities to apply the money in directions which will actually give the greatest results.

THE LABORATORY AS AN AID IN WATERSHED PROTECTION

In a number of the larger cities, the unfiltered water supplies are controlled to better advantage as a result of current data from water laboratories than would otherwise be the case. This results not only from tests at frequent intervals to show the extent of pollution at points known to be open to pollution, but also from tests of water in streams feeding reservoirs as well as the water in reservoirs themselves, which furnish considerable information of practical value in maintaining the supply in a condition moderately free from color, turbidity, tastes and odors.

The vast majority of water supplies are not subjected to frequent analyses in the laboratory of the water department, although a great deal of aid is secured from the analyses made from time to time of samples sent to outside laboratories, especially those of State Departments of Health or of State Water Surveys.

In instances where the aid of the laboratory may be secured only infrequently or perhaps not at all, it is important that those in charge of the water supply which is not filtered should make an unusual effort to derive full benefit from frequent, careful inspection of various conditions on the watershed related not only to pollution, but to matters associated with the appearance of the water and its tastes and odors.

NEEDED LEGISLATION TO PROVIDE AUTHORITY FOR WATERSHED PROTECTION

A great many of the states and provinces have adopted acts of the Legislature prohibiting the pollution of streams from which public water supplies are derived. Such statutes are founded upon the police powers of the sovereign states and procedures are set forth whereby the State Department of Health takes jurisdiction in carrying out steps under various local conditions.

There is a wide variability in the laws of different states and there is need of variability as to rules and regulations depending upon the local conditions of particular watersheds. This is shown by the fact that different rules and regulations have been set forth in some

particulars by the same state health authority, as for instance, in Massachusetts, where numerous sets of rules have been promulgated.

The Committee finds that it is out of the question at this time to attempt to unify statutory regulations in the different states, although there is a great deal that may be done towards coördinating and improving the practical accomplishments which come from state regulation.

It is only necessary here to point out that fishing and bathing are prohibited in some supplies even where filters have been adopted, while in the instance of unfiltered supplies elsewhere, bathing and boating are permitted by definite enactment.

The influence of this Association should be directed toward the restriction by statute of all activities tending markedly to pollute unfiltered water supplies and those tending to pollute filtered water supplies to such an extent as to overload or to threaten to overload seriously ordinary purification processes.

Another point upon which the position of this Association should be made clear is that statutory procedures and the regulations promulgated by health authorities should carry with them a practical and effective program for punishing those who violate the rules made in the interests of public health. That is to say, it is of comparatively little benefit to set up statutes aimed to protect the purity of inland waters and to follow them with rules and regulations as a guide to local authorities in proceeding under such statutes, if those in charge of the water supplies have no ready effective means of punishing all who offend the rules and regulations. Obviously, a law or a rule which may be broken with impunity is no better than no law at all.

MEANS OF ENFORCING STATUTES AND REGULATIONS AIMED TO PROTECT WATER SUPPLIES

This question has two aspects. One relates to the establishment of what may be termed police patrol or inspectors on a watershed, and the other deals with procedures for punishing those who violate the rules. The latter question is one on which the Committee desires to secure experiences from members of the Association, because it is believed that the arm of the law has not ordinarily been of great help to those in charge of the protection of water supplies.

It is too easy to circumvent the provisions of the law and actions in courts, dragging along for months and years, have produced a spirit of indifference on the part of the residents of a watershed. They learn that they are not likely to be punished severely by any court or jury resident in the vicinity and their humane interests in the water users of a neighboring city are remote in comparison with their own individual wishes and time honored customs.

As to the means of patrolling the watershed to guard it against objectionable pollution, the best procedure is not capable of ready definition. Some prefer to use residents of the locality who will talk tactfully the language of the district and will do a great deal of good in restricting gross pollution. Others who are connected with the watersheds of larger cities favor police patrol with men mounted and uniformed and equipped with authority to enforce the law. A discussion of the relative merits of these two procedures should furnish information which the Committee has had difficulty in procuring by correspondence.

All measures of preventing the pollution of water supplies that are used or may be used without involving unreasonable costs are well worth while, but are not thoroughly effective even when the entire watershed is owned. They should be carried out thoroughly in an attempt to maintain the greatest possible degree of purity in supplies which are drawn unfiltered, but where filtration is provided the steps taken to control the quality of the raw water may be satisfactorily and most economically directed toward the elimination of gross sources of pollution.

PRELIMINARY REPORT OF COMMITTEE ON ESSENTIAL DATA FOR WATER WORKS RECORDS AND REPORTS[1]

PART A. MUNICIPAL PLANTS

Committee correspondence indicates that it is highly important to unify views on certain questions of fundamental policy before real progress with details can be made. A meeting has been arranged in Detroit for the afternoon of May 21, to which all members of the Association have been invited. The purpose of this meeting is to exchange views on matters of policy and upon detail procedures indicating where improvements may be made in the records and reports of water plants.

Briefly stated the present view of the committee is to use its influence towards securing more adequate office records and to publish summaries of them in such manner as to allow ready comparison to be made with the records of more or less similar water plants elsewhere. In addition, its purpose is to urge the preparation of reports which will be of value to the citizens and to civic organizations along lines more or less approaching the recent concise and interesting reports from private corporations. Such reports should deal with the more ordinary essential data and programs, reserving for special reports information dealing with extensive plant improvements and the like. Such special reports should appear on special occasions as required and not annually.

Descriptions of existing works and of their performance should appear in annual reports and be supplemented by statistics, readily

[1] This report has been prepared under the direction of Council to facilitate discussion of material secured by the two branches of this committee, as follows:

Personnel of Committee for Municipal Plants: George H. Fenkell, Chairman, Detroit, Mich.; Carleton E. Davis, Philadelphia, Pa.; Charles S. Denman, Des Moines, Ia.; Charles A. Finley, Pittsburgh, Pa.; R. B. Howell, Omaha, Neb.—and for Privately Owned Plants: John N. Chester, Chairman, Pittsburgh, Pa.; Dow R. Gwinn, Terre Haute, Ind.; Allan W. Cuddeback, Paterson, N. J.; Robert J. Harding, San Antonio, Tex.; Frank C. Kimball, Summit, N. J.

comparable with corresponding data from other plants. The scope and arrangement of such information need discussion before the committee reports in detail.

Mention is made of the fact that some members of the committee have coöperated with G. W. Fuller, Chairman of the Council on Standardization, in arranging notes describing the Philadelphia water works, on which a lantern slide talk was given at the Philadelphia convention. A description of the Philadelphia works appears in this number of the Journal and it has been suggested that it might be used as a target for criticism and suggestion in discussing the extent to which water works should be described in reports.

The committee requests in particular an expression of views from the membership on the following points:

1. Office records should be complete as to location, arrangement and extent of existing works; and, where not complete, should be made so.

2. Office records should show all financial transactions with accounts classified according to some recognized system; with suitable segregation between disbursements for operation and maintenance, renewals and replacements, and extensions and betterments.

3. Office records should show summaries of operating costs arranged to allow comparison to be made month by month and year by year with earlier records of the same plant as to pumping, filtering, pipe line maintenance, meter repairs, etc.

4. Office records should show the estimated quantity of water used by large industrial and commercial consumers; estimated average water used for domestic purposes by the city as a whole, or by certain portions, depending upon the extent of meterage; and with information summarizing available data as to the portion of total supply unaccounted for.

5. Annual reports should not show records of structures such as valves, hydrants, pipe extensions and location of same.

6. Annual reports should not show detailed vouchers of disbursements.

7. Annual reports should show a summary of plant extensions for the year and a brief descriptive summary of the plant as a whole.

8. Annual reports should show in summarized form such information as is available as to the capital account for the existing works as a whole.

9. Annual reports should show financial statements with description summarizing operating records with the specific purpose of throwing light on the economy and efficiency attending operation of the plant in question, as compared with earlier performances.

10. Annual reports should show a budget for the ensuing year.

11. Annual reports should show any special features required, such as unusual renewals.

12. Annual reports should show in summarized form the essential information contained in any special reports as to plant extension, change in financial policy, such as rates of charges, organization, etc.

13. Special reports should be prepared and be available for distribution to consumers and civic organizations setting forth in a plain and non-technical manner the essential features for programs as to extensions and other unusual features. Such special reports may be included as an appendix to annual reports, but should be available for distribution when and as required.

14. As appendices to annual reports, operating statistics should be attached in conformity with the form prescribed by the N. E. W. W. Association and the American W. W. Association, as modified and supplemented by more recent practice and as should be developed by the discussions to be conducted by this committee.

PART B. PRIVATELY OWNED PLANTS

Water companies must conform, of course, to the requirements of the state regulatory commissions and this outline has been prepared to present a fair average picture of such requirements as far as the knowledge of the compilers would permit.

Population of city
Population served
Total number of consumers
Number of industrial consumers
Percentage of consumers metered
Type of supply:
1. Gravity
2. Pumping

Type of plant:
1. High level reservoir
2. Standpipe
3. Direct pressure

Source of water supply:
1. Flowing stream or lake
2. Impounded stream
3. Wells
4. Springs

Type of purification:
1. Natural sedimentation
2. Coagulation and sedimentation
3. Slow sand filtration
4. Mechanical filtration
   a. Gravity type
   b. Pressure type
5. Iron removal or deferrization
6. Softening
7. Sterilization

Boilers:
1. Fire tube
2. Water tube
3. Marine
4. Stokers or hand fire
5. Type of ash equipment, if any
6. Operating steam pressure
7. Total rated horse power of boilers

Pumping machinery

High service head, in feet
Low service head, in feet
Steam driven:
  Engine driven centrifugal
  Turbine driven centrifugal
  Direct Acting:
    Simple
    Compound
    Compound, condensing
    Triple expansion, condensing
  Crank and fly wheel:
    Horizontal compound
    Vertical compound
    Horizontal triple-expansion
    Vertical triple-expansion
Electric driven:
    Centrifugal
    Reciprocating
Internal combustion engine driven:
    Centrifugal
    Reciprocating.
    Classify both high, low and booster service machinery as above, giving capacity of each unit

Operating data

Pumpage—how measured or computed
Amount pumped, or delivered to mains
- Gross annual—gallons
- Average daily rate
- Maximum month—daily
- Maximum week—daily
- Maximum day
- Maximum hour—daily
- Average daily to booster service

Industrial consumption
Per capita consumption—other than industrial

(For steam plant)
Kind of fuel:
- Oil, gas, lignite, bituminous or anthracite coal

Quantity of fuel consumed annually
Pounds of fuel required to raise each one million gallons 100 feet high =
Station duty =

$$\frac{\text{Total gallons pumped} \times \text{head in feet} \times 8\frac{1}{3}}{\text{Total hundred weight of coal burned}} =$$

Steam used for other purposes

(For electrical)
Gross k.w.h. electricity consumed
K.w.h. required to raise each one millions gallons 100 feet high
Overall pump and motor efficiency

(For internal combustion)
Gross cubic feet or gallons consumed
Gross fuel cost
Fuel cost of raising each million gallons 100 feet high
Labor cost of raising each million gallons 100 feet high

Water and treatment data

Turbidity (in parts per million):
- Maximum
- Minimum
- Average annual

Coagulant and chemical (in parts per million):
- Average iron
- Average alum
- Average lime
- Average soda ash

Sterilization agent (in parts per million):
- Chlorine or hypochlorite of lime

Filtration operating costs—average, per million

Rate schedule

Domestic:
  Ordinary minimum charge
  Ordinary service charge
  Charge for 1000 gallons
Industrial:
  Highest minimum charge
  Highest service charge
  Lowest consumption charge per 1000 gallons

PROGRESS REPORT OF COMMITTEE ON METHODS AND RECORDS OF WATER WASTE CONTROL[1]

General. The committee presents herewith a progress report which has been drawn with the expectation that the grouping of facts, in a somewhat different manner than heretofore, which are known to water works men will elicit discussion and add to the interest taken in water waste prevention. The committee also covers rather briefly the subject of size of tap, service pipe and meter to be used and reasons therefor. It is expected that this report will later be amplified and a final report submitted at the 1924 convention. In this preliminary report all the statements made are not necessarily specifically approved by each member of the committee.

Water waste. The waste of water has been a source of expense to the community and of trouble to the water superintendent from the time of the earliest water supply systems to the present time. Nearly 2000 years ago, Frontinus, then water commissioner of Rome, wrote feelingly on this subject, complaining of the carelessness and dishonesty of his consumers, and of his difficulty in accounting for the water delivered through the aqueducts. Today, the same problem is always with the water superintendent, but he is better equipped to solve this problem through the use of modern devices to measure water and record its use.

The waste in a water supply system is defined as water which is not drawn to serve a useful and legitimate purpose. The drawing of water for a useful purpose, such as cooling milk by a running stream, or operating a water motor, is waste of water where the rules do not permit water to be drawn for such purposes. Water drawn to serve a legitimate purpose, such as washing of street and sidewalk pavements, may be wasted in part due to an excessive amount being drawn. The loss through leakage, both from the underground

[1] This report has been prepared under the direction of Council to facilitate discussion of material secured by the committee, the personnel of which is as follows: William W. Brush, Chairman, New York; George C. Andrews, Buffalo, N. Y.; Henry P. Bohmann, Milwaukee, Wis.; Edward S. Cole, New York, and Charles S. Foreman, Kansas City, Mo.

pipes and within buildings, constitutes the most important waste of water, and is that to which your attention will generally be directed. Waste of water from reservoirs and aqueducts presents special problems which it is believed should not be discussed by your committee.

"Water unaccounted for." The phrase "water unaccounted for" is one that has been or may properly be used in analyzing every water supply system, and has been given various meanings. It is proposed that the following definition should be used for the sake of uniformity, clearness, and facility in comparison of different systems. "Water unaccounted for" is that portion of the water flowing into a distribution system which is not delivered to the consumers. The accuracy with which this "water unaccounted for" may be determined is dependent upon the number, location, and reliability of the measuring devices installed on the delivery mains, services and other appurtenances, and on the skill and care of the official estimating the amount of water delivered to consumers, where there is no measuring device giving a continuous record. In all water supply systems there should be some portion of the water delivered determined by estimation, based, however, on careful and sufficiently extensive tests, as there is always slippage on meters and use through hydrants which will not be shown by the record of the meters and other measuring devices, even when the system is properly stated to be 100 per cent metered. The leakage or loss of water in the system between the point where the water enters the system and where it is delivered to consumers should be considered as "water unaccounted for," even if measurements have been made which show this amount with a considerable degree of accuracy. The slippage of meters deducted in determining the "water unaccounted for" should always be definitely stated in conjunction with the "water unaccounted for," as this item is a variable and important one and in a general way reflects the efficiency of meter maintenance.

Water measurement. The determination of waste of water and its stoppage is fundamentally based upon continuous and accurate measurement and record of the amount of water delivered into the distribution system. In pumped supplies the discharge of the pump is commonly used, but such discharge should be corrected for slip, computed by accurate measurements of actual pump delivery, using a pitometer or similar instrument. The checking up of the pump slip should be made at least once a month, and more fre-

quently if tests show the pump slip to vary materially. Tests should also be made whenever a pump is repaired. It is desirable to have a venturi or some other form of meter to give a continuous record of the pump discharge, rather than to use the number of revolutions of the pump.

In gravity supplies a meter of some form is essential, such as a venturi meter, pitometer, current meter or displacement meter, the first two being the type which may be used without raising a question of interference with the flow from a fire protection standpoint.

After the flow into the distribution system has been established satisfactorily and so the demand for each part of the twenty-four hours in the day may be fixed, the measurement of flow into the different parts of the system, and through the service pipe, to the consumers, becomes important, but may not be imperative. This latter portion of the work will be considered hereafter.

Conditions under which water waste prevention work should be undertaken. When water waste prevention work should be actively prosecuted and what method should be followed, are questions whose answers depend on several factors, some of which may not be definitely fixed. It will be helpful to discuss this phase of the subject under the two headings, subsurface waste and plumbing waste.

Subsurface waste covers that occurring on mains, valves, hydrants and services, while plumbing waste is that which occurs within the building. Unless water waste prevention work has been actively prosecuted it is reasonable to assume that waste exists which may be stopped. If the services are generally metered, then a comparison of the amount of water flowing into the distribution system with the amount accounted for by the meters, together with that estimated to be used through unmetered connections, including hydrants, will show the amount unaccounted for. It is generally considered that this amount should not exceed twenty-five per cent, and by careful work it may be reduced to ten per cent. or even less. The cost of correcting sub-surface waste would vary greatly, depending largely upon the character of the soil, the street pavement, depth of the mains below the surface, number and location of the leaks, interference of sub-surface structures with tests, and other less important factors. Whether the financial returns from an effort to stop the sub-surface leakage would be sufficient to warrant undertaking the work would depend largely upon how much water could be saved, and what would be the cost of furnishing such water if the waste were not stopped.

Obviously, if the community would have to develop additional supply unless waste were stopped, the amount which might be justifiably spent on waste prevention would be large. Again, a pumped supply would warrant a higher cost for waste prevention than would an ample gravity supply.

An illustration of the varying cost to the community of the water which is wasted is afforded by New York. When the Catskill system was first utilized in 1917 and about 375 m.g.d. made available, the Brooklyn and Richmond systems were placed in reserve and the draft from the Croton system was cut in half. The cost of any additional water delivered by gravity from the Croton system was about $0.25 per million gallons, as this cost was limited to the chlorine required to treat the water, the system of collecting works, aqueducts and distribution mains being adequate to deliver the additional quantity to provide for the waste of water, and no additional force being needed to operate the system. If the Croton water had to be pumped, as would be the case where waste occurred on the higher ground, then the cost was about $10.00 per million gallons. If Brooklyn water had to be drawn on to make good the waste the cost increased to about $25.00 per million gallons, and when the Richmond supply was needed for this purpose the cost was about $20.00 per million gallons. When New York reaches the time when the construction of the works for an additional supply beyond that from the Catskill system must be started, and that time is close at hand, then each year that the starting of such construction is safely postponed due to stopping waste would mean a saving of over $10,000,000 per year, which would make the value of the water then saved over $500.00 per million gallons. Care must be exercised in the use of any figure like the one last given, as the delays in carrying through any enormous water supply project like that needed to serve New York for another twenty years growth are such as to necessitate the time allowed being determined with several years leeway, if provision for the future is to be safely made.

While New York's problem is a large one, the principle upon which the foregoing estimates are based is a sound one for any community, large or small.

The use of the per capita consumption and the ratio of night consumption to average daily consumption to determine when waste prevention should be started are usually the most helpful data. They must, however, be used with some caution. Per capita con-

sumption varies so greatly, and from so many causes, that it is only after a most careful consideration of the existing per capita consumption and night rate demand that any conclusion may be safely drawn. So much has been published about consumption, and the subject was so well covered in 1913 by the New England Water Works Association, through a committee of which Leonard Metcalf

TABLE 1

Population, services, per cent of services metered and per capita consumption in the metropolitan water district, Massachusetts

	POPULATION		SERVICES		PER CENT OF SERVICES METERED		PER CAPITA CONSUMPTION	
	1910	1920	1910	1920	1910	1920	1910	1920
Arlington	11,270	18,780	2,050	3,318	62.83	100.00	83	56
Belmont	5,600	10,880	909	1,903	100.00	100.00	59	54
Boston	674,400	751,810	93,780	107,708	19.96	62.46	130	125
Chelsea	32,500	43,380	4,790	5,256	64.34	99.35	87	76
Everett	33,710	40,350	5,380	6,140	22.04	71.30	76	83
Lexington	4,440*	6,390	836	1,353	56.82	98.97	78	66
Malden	44,730	49,350	7,440	8,406	96.28	97.38	42	57
Medford	23,330	39,460	4,550	6,892	94,42	100.00	61	44
Melrose	15,790	18,270	3,583	4,480	100.00	98.86	64	61
Milton	7,970	9,420	1,454	2,216	100.00	100.00	39	46
Nahant	2,100†	1,330	532	774	42.67	74.81	58	145
Quincy	32,870	48,200	7,307	11,027	36.05	91.66	88	93
Revere	18,500	29,120	3,454‡	4,822‡	25.80‡	80.77‡	71	68
Somerville	77,640	93,530	12,149	13,614	47.82	77.84	80	77
Stoneham	7,130	7,890	1,467	1,696	43.29	99.65	91	100
Swampscott	6,960†	8,150	1,478	2,011	99.12	100.00	59	81
Watertown	12,960	21,530	2,042	3,471	100.00	100.00	68	89
Winthrop	10,290	15,590	2,487	3,018	95.94	99.54	63	56
Totals	1,022,230	1,213,430	156,688	188,105	37.31	74.70	110	105

* Allowance made for district not supplied.
† Allowance for summer population.
‡ Includes small portion of Saugus.

was chairman, the report appearing in the New England journal in Vol. 27, page 29, that it does not appear necessary to tabulate extensively consumption figures. Table 1 gives the per capita consumption of the cities and towns in the Massachusetts Metropolitan Water District for 1910 and 1920, and also shows the percentage of services metered. These data are representative of both wholly and

partially metered communities in the east and would not necessarily apply to communities in other sections of the country.

It is significant of the variations which may occur to note that in Detroit, Michigan, which is now a virtually completely metered city, very different results are obtained from those in one of our New England cities, as shown by the following comparison:

CITY	POPULATION	PER CENT METERED	DAILY CONSUMPTION PER CAPITA	PERCENTAGE OF FLOW FROM 1 TO 4 A.M. COMPARED WITH DAILY RATE
Detroit, Mich.	1,000,000	98	135	66
Hartford, Conn.*	122,000	86	70	53

* Figures refer to 1912.

In a small New England community, such as Milton, Mass., with a population of some 10,000, the per capita consumption is about 40 gallons daily, and the minimum night flow at the rate of 10 gallons, or about 25 per cent of the daily average. In Detroit, in May, 1919, a pitometer survey of the distribution system was started, it being expected that about 20 m.g.d. could be saved by stopping underground waste. After an area had been surveyed covering eighty per cent of the population and fifty per cent of the miles of mains, only about 7 m.g.d. in underground leakage had been discovered. This example illustrates the difficulty of estimating in advance the results to be gained from sub-surface water waste prevention work.

With plumbing waste a more definite determination may be made by examining a given number of typical premises and estimating the total leakage and the proportion that is preventable, and then determining whether or not the waste prevention work should be started.

METHODS FOR SUB-SURFACE LEAKAGE

Pitometer surveys. The most generally used method to locate subsurface leakage is to measure the flow through the mains by tapping the main with a one-inch cock, and inserting a pitometer, using a portable continuous recording device for the period of time desired. It is usually advisable to place a permanent manhole over the tap so that it may be readily used for subsequent surveys. The area to be surveyed is divided into a convenient number of districts,

so arranged that, if possible, one instrument may measure the flow into the district. The district is formed by closing gates on the boundary, and care must be exercised to provide sufficient water to meet a sudden demand caused by a fire in the district. After the district is formed and the normal flow measured, the district is reduced by cutting off one or more blocks at a time, doing this work at night when the demand is at a minimum. The record of the pitometer will show how much reduction in flow is caused by each section of main shut off. Those sections which indicate a suspiciously high flow are further investigated, by pitometer or aquaphones, and the cause of the high flow ascertained. Usually it is found that one or more leaks exist on the main or services under suspicion. This method is one that must be carried out by men skilled in the use of these instruments if it is to be successful. The system is practically the same as that followed when the Deacon meter was used. Boston, Mass. used that system extensively some forty years ago, but today the pitometer takes the place of the Deacon meter.

Hose and meter surveys. To determine the flow in one or more blocks a meter, usually of the 2-inch disc or current type, may be connected by hose lines to two hydrants, and the mains to be tested supplied by opening the two hydrants and closing valves, so that all the flow must pass through the meter. By mounting the meter on a light auto truck additional facility of measurement is afforded. This system requires many more measurements to be taken than the pitometer system, and is not so generally used, but the principle is virtually the same. In small systems, where comparatively few tests are required to cover the distribution system, the hose and meter test may be advantageous over the pitometer method, but ordinarily the pitometer is to be preferred due to the more rapid progress made, the establishment of permanent points of measurements, and elimination of interference with the flow through the main pipe feeding the district.

Aquaphone surveys. The aquaphone is one of the most valuable of the devices available to aid in locating hidden leaks. It cannot tell you whether leakage does or does not exist on a given long section of main or what is the rate of flow through the mains, but it can reduce greatly the cost of locating leaks after it is known that one or more leaks are on a certain section of main, on services or on other connections. If the superintendent will regularly use an aquaphone on valves, hydrants, services at point of entry into

buildings, and at curb cocks, he may locate and correct at a minimum of expense all sub-surface leakage other than that on the mains and blowoff or similar connections and may frequently locate even these latter leaks. By combining the tests of flow in mains with aquaphone tests, all leaks that are of sufficient size to justify their stoppage may be located and eliminated. Small diameter rods driven down to the main greatly aid in locating leaks and avoid disturbances of pavement. The superintendent must judge for himself when he has reached the economic limit of search for underground leaks, by comparing the cost of locating the leaks with the value of the water saved by stopping the leaks. The time interval before making a reinspection by aquaphone must also be determined for each community and for each group or class of pipe and appurtenances. In general, it may be considered good practice to test hydrants once a year, house services once a year, more or less depending upon whether the inspectors visit the premises for other purposes, and the mains about every two years.

In Buffalo, where the pitometer system is used, with the aquaphone as an aid, and house to house inspection for building leakage, the entire system was covered in three years. With a permanent pitometer force of 4 men the city is resurveyed at an interval of from one to two years.

In New York the force available for underground leak detection work has never been sufficient fully to cover the locations where it is known leaks exist. The aquaphone is therefore generally used with rods driven down to the main furnishing the most helpful means of securing the necessary sound for location of leaks. The force employed since the latter part of 1919 has been three assistant engineers, 4 engineering assistants, 16 skilled and unskilled laborers. The labor force has been divided into four gangs each with its 1½ ton auto truck. Prior to 1919 the labor force was about one-half the present force. During 1922 the estimated cost for salaries, wages and supplies was $49,144 and 291 leaks averaging 62,155 gallons per day were stopped. On the assumption that the leaks found and stopped would have remained unchecked for two years, if the special force had not been assigned to this work, the estimated cost of water saved is $3.62 per million gallons.

The following table is a record of this work since it was commenced in 1910.

YEAR	DESCRIPTION	LEAKS LOCATED AND REPAIRED	STOPPED M.G.D.	COST PER M.G. SAVED
1910	River crossings	2	4.00	
1911	Manhattan Waterfront	17	3.50	
1912	General waste surveys	33	3.80	
1913	General waste surveys	56	5.40	$3.55
1914	General waste surveys	64	11.00	3.24*
1915	General waste surveys	106	7.20	2.52
1916	General waste surveys	149	12.25	1.34
1917	General waste surveys	158	11.35	1.15
1918	General waste surveys and investigations of reported leakage	150	11.26	2.08
1919	General waste surveys and investigations of reported leakage	173	9.35	3.19
1920	General waste surveys and investigations of reported leakage	305	19.77	2.79
1921	General waste surveys and investigations of reported leakage	312	16.27	3.83
1922	General waste surveys and investigations of reported leakage	291	18.09	3.62

* Two large leaks totaling 5.5 m.g.d. excluded in computing cost.

$$\text{Cost equals } \frac{\text{total cost of work}}{\text{m.g.d. saved} \times 365 \times 2}.$$

With the trained men the number of street openings per leak averages only about one and one-quarter, although leaks are found a block or more from where there is visible evidence of the leak in a cellar or other low spot, and some of the leaks found are known to have existed for nine or more years.

PLUMBING WASTE

General. The term plumbing waste is used rather than plumbing leakage, as waste is a more comprehensive term and more descriptive of what occurs. In the underground portion of the water supply system the escaping water is all leakage except where a blowoff has been inadvertently left open. In the buildings there are usually many leaks, but there may also be waste, even where the service is metered. The subject will be treated under unmetered and metered premises.

Unmetered premises. These premises are those where the greatest waste of water takes place, the amount depending upon many factors. Where buildings are occupied by the owners for residential purposes the leakage and waste is likely to be small, as the owner is a taxpayer, realizes the cost of waste to the community, and is of the more saving and industrious portion of the population. It is doubtful whether there is any net advantage to be derived from inspecting or metering such premises. Where premises are rented, tenants are more careless and landlords are less personally interested in the building other than as a money making proposition. It is figured that it is cheaper to let the water waste than to have a plumber make repairs. Where house services are laid at insufficient depth to afford protection from frost, or where the supply pipes in the building are also insufficiently protected, the water will be allowed to run continuously, and frequently in a full stream, for weeks at a time. The use of water motors for power, the running of water over milk bottles and other receptacles to keep the contents cool during the summer, are instances of waste found in most communities. There is no known adequate remedy for such waste except metering. The only other method of value are house to house inspection and education of the public on the subject of stopping waste, using printed matter and pictures. The appeal to the school children is probably the most effective educational method.

House to house inspection, if backed up by fines for allowing waste to continue, will accomplish very material reductions in water supply demands. The usual custom is to have the inspector visit the premise and notify the owner or tenant to have any leaks repaired. A reëxamination is made in a week to ten days time and, if repairs have not been made, some form of punishment is provided, such as a fine or cutting off of the supply. A pitometer survey should be made in connection with a house to house inspection to determine the rate of consumption before and after the inspection, and consequent saving. In some systems it is customary to listen at night at the curb cock to determine whether there is likely to be any waste found on a premise and to inspect only those which are suspicious. Other places determine the flow in each block and pass upon whether the block as a whole shows high demand, especially during the period from midnight to 4 a.m. The time interval between inspection should be determined by the local conditions in each community, but worth while results may usually be obtained with yearly inspections. After a lapse of two years all effect of a

previous inspection will have disappeared. For New York conditions it is estimated that a force should be made up of one supervising man for each 12 inspectors, and one clerk for each 5 inspectors. Where there is a two year interval between inspections the saving for each inspector employed, if all leaks found are stopped, will average one million gallons daily. In other words, one inspector employed continuously in a territory that may be covered in two years' time, will effect, at the end of the two years, an average saving of one million gallons daily, and thereafter will maintain this saving. When house to house inspection was being actively carried on in Brooklyn, prior to the introduction of Catskill supply, and when pitometer measurements were taken before and after inspections, the results obtained were those shown in the following table:

DISTRICTS	CHARACTER	DAILY CONSUMPTION BEFORE INSPECTION	DAILY CONSUMPTION AFTER INSPECTION	SAVING	SAVING
		gallons	*gallons*	*gallons*	*per cent*
1, 2	Mainly business and manufacturing	23,884,000	21,547,000	2,337,000	10
3*	Manufacturing and shipping	13,000,000		2,200,000	17
4, 5	Mainly resident medium-class	17,908,000	14,078,000	3,830,000	21
6, 7	Partly residential and business	12,713,000	10,343,000	2,370,000	19
8	Shipping and low-class tenements	9,250,000	7,750,000	1,500,000	16
9	Shipping and low-class tenements	6,733,000	5,396,000	1,337,000	19
10	Manufacturing and low-class dwellings	9,783,000	6,807,000	2,976,000	30
11	Medium-class residential	9,610,000	7,110,000	2,500,000	26
12, 13*	Medium-class residential	12,261,000		3,065,000	25
17, 23*	High and medium-class residential	10,049,000		2,010,000	20
Total		125,191,000		24,125,000	19†

Saving $\frac{24,125,000}{125,191,000}$ equals 19 per cent

Cost of pitometer gagings	$7,200.00
Cost of inspectors, clerks, etc.	29,500.00
	$36,700.00

* Indicates districts in which the saving has been estimated.

† Average.

The consumers generally are opposed to the visits of the inspectors and this method is not popular.

Where there is known to be leakage of substantial amount, either in or outside of buildings, and when the night pressure materially exceeds the day pressure, the reduction in pressure at night to the day pressure will lower the amount of waste. This method must be used with great care to prevent any danger of insufficient supply for fire extinguishment and to make certain that the higher night pressure is not reasonably required to meet demand for filling tanks where day pressure is low.

Metered premises. At times it is assumed that (*a*) meters stop all waste of water and (*b*) all water delivered into the building is paid for. Neither of these assumptions are true. Meters will not stop that waste of water which the occupant is willing to pay for. The lower his water rate the more he is willing to waste. Thus, in Detroit, it is known that there is a good deal of water wasted, even though the meter correctly records the delivery and draft, but the consumers would rather pay the higher bills than stop waste, and the per capita consumption is about 135 gallons daily. Where there is a high minimum charge waste is likely to occur, as even with the waste included the water recorded does not equal in cost the minimum charge. This fact is an important argument against high minimum charges. Where conditions as to existing supply and additional available sources make it imperative that all preventable waste should be eliminated, inspection of metered premises should be undertaken.

The under-registration of meters, due to slippage and other causes, is a factor which is too often given minor consideration by water commissioners, and to a less extent by water superintendents. Mr. Caleb M. Saville, in his excellent paper on "The selection of meters," New England Water Works Journal, page 329, December, 1918, shows that meters are recording flows at rates within their high accuracy range for only a very small percentage of the time, and the importance of selecting meters of the correct size and type for the service to be performed. The need of regular examination and test of meters is supported by all who have studied this question. While the time interval will vary under different quality of water and conditions of service, it appears reasonable to fix the outside limit of five years for small meters, reducing gradually to one year for the larger meters. Mr. D. W. French reports in This Journal, Vol. 6,

page 34, March, 1919, the practice of the Hacksensack Water Co. for the past twenty years and the recent rules of the Board of Public Utility Commissioners for New Jersey in reference to replacing meters. The data given are as follows:

SIZE OF METER	MAXIMUM REGISTRATION ALLOWED BEFORE METER IS REPLACED		MAXIMUM TIME IN SERVICE BEFORE METER IS REPLACED NEW JERSEY BOARD
	Hackensack Water Co.	New Jersey Bd.	
inches	*cu. ft.*	*cu. ft.*	*years*
½	100,000	750,000	10
¾	250,000	1,000,000	8
1	500,000	2,000,000	6
2	2,000,000	No quantity given	4

Where wide ranges of flow are experienced, compound meters afford an opportunity to measure more accurately the water supplied.

SIZE OF TAPS, SERVICES AND METERS

General. There has been comparatively little study given by water works men to the formulation of a logical definite system or practice on the size of taps, services and meters, and their proper relation one to the other. Here is a field in which the experience of many should be secured to furnish adequate data on present practice and to aid in setting up a more generally used standard for the future. The committee has not secured the data it should have to pass upon the questions involved, and will set forth, therefore, some rather general observations, expecting that later much more definite statements and recommendations may be submitted.

Taps. It appears to be rather generally agreed by water superintendents that taps may properly be one size smaller than the service pipe, but this is not to be considered a rule that is always followed. It is logical to have the tap or corporation cock smaller than the service, as the loss in head at the corporation cock is largely that due to entry of water into the tap from the main and is equal to the friction loss in the same sized service for the various sizes of pipe, as follows:

SIZE	RANGE OF DISCHARGE PER MINUTE	LENGTH OF LEAD PIPE TO GIVE SAME LOSS OF HEAD AS TAP
inches	*gallons*	*feet*
½	3–23	4.3
⅝	6–35	5.5
¾	8–50	6.4
1	14–100	8.6
1½	70–250	11.2
2	60–400	25.6

The above data have been taken from the paper by B. J. Bleistein, This Journal, vol. 5, page 240, September, 1918. The figures given for loss in head represent averages and more detailed data are furnished by Mr. Bleistein.

There appear to be comparatively little data as to the basis on which the size of taps has been determined. It would seem that 5/8 or 3/4 inch taps might be adopted as the minimum size, using the practice of the majority of communities. New York has been successfully using the floor area basis, for about ten years as set forth hereafter under quotations from the proposed rules and regulations that are now being considered by the New York Department.

Size and number of unmetered taps. The size and number of taps or connections for an unmetered supply to any building shall be computed upon the floor area of said building. The floor space shall be computed by multiplying the area which the building occupies by the number of floors. The floors to be computed in this calculation shall be only those which separate the stories on which are fixtures the department would consider in fixing a frontage rate. The area of the building shall be computed from the general over-all dimensions, exclusive of small projections, such as bay windows, porches, etc. Extensions shall be computed in the same way and added to the floor space of main building. An extension to be included shall have a floor space of at least 150 square feet per floor. The resulting figures shall be called the next higher even thousand, thus 217,436 shall be considered as 218,000 square feet.

The area of one ⅝ inch tap shall be credited for the first 7500 square feet, one ¾ inch tap for the first 15,000 square feet, and above 15,000 square feet, one ⅝ inch tap for every additional 10,000 square feet of floor space.

"The total number of ⅝ inch taps computed shall be reduced to a larger sized tap in accordance with the following table:" (See figure 1 attached to the end of this report).

Size. When the floor area of an unmetered premise entitles it to a number of ⅝ inch taps, the total area of which is equivalent to a larger standard size tap and 50 per cent or more in excess thereof, the next larger standard size tap shall be granted.

Flushometers and part business. Taps in number and size greater than those specified above may be allowed upon the written approval of the deputy commissioner or borough engineer, who is to state whether the increase in tap area is allowed on account of the use of flushometer closets or other causes. Where a building is to be used in part for business and in part for domestic purposes, additonal taps may be permitted upon the approval of the engineer, where the character of the business conducted is such as to require a quantity of water which could be consistently considered above normal use for ordinary business purposes.

Size of metered taps. If a building is entirely metered, the next larger tap than that permitted in unmetered premises will be granted upon application of the owner. Where a tap in excess of this size is desired the application shall only be granted on approval of the borough engineer or deputy commissioner. The borough engineer or deputy commissioner may require the filing of an affidavit by the owner of the premises requesting the excess tap area, specifying the reasons for the necessity and agreeing to plug the excess tap in the event of change of occupancy in the premises.

Services. In fixing on the size of service, the character of the material used for the service and the probable reduction in capacity due to clogging should be given weight. It is believed that satisfactory water service may best be given by a fairly liberal policy as to size of tap and service, and a cutting down on the size of meters. The meter may be readily changed at a small expense and with no inconvenience, while the tap and service may be replaced only through excavating in the public street and expending a substantial sum. For the purposes of discussion the New York proposed rules on services are quoted.

Minimum and maximum diameters. The minimum diameter of a service pipe shall be ¾ inch and the service pipe shall be not less than the diameter of the tap controlling it.

The maximum sizes of services allowed are as follows:

DIAMETER OF TAP	DIAMETER OF SERVICE PIPE
inches	*inches*
⅝	1¼
¾	1½
1	2
1½	2½
2 or wet connection	3
3 ditto	4
4 ditto	6
6 ditto	8
8 ditto	10

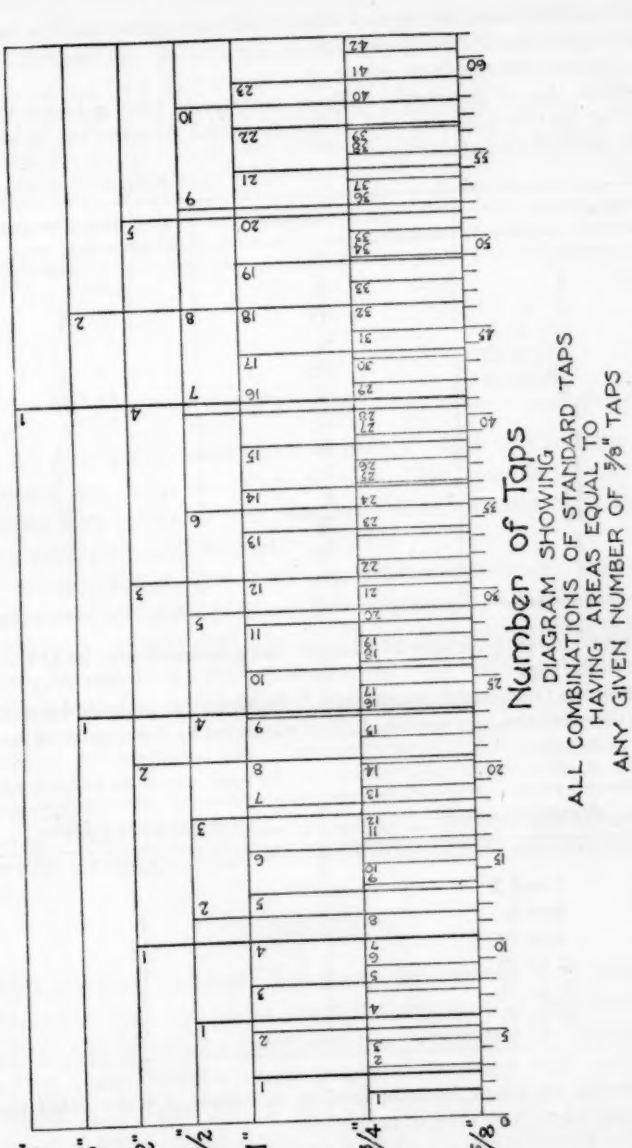

Size of Taps
4"
3"
2"
1½"
1"
¾"
⅝"
Number of Taps
DIAGRAM SHOWING
ALL COMBINATIONS OF STANDARD TAPS
HAVING AREAS EQUAL TO
ANY GIVEN NUMBER OF ⅝" TAPS

Fig. 1

On wet connections, larger than those listed, the service shall be the same size as the wet connection, except when approved by the borough engineer or deputy commissioner in writing.

Minimum size of goosenecks. Where the service pipe is larger than the controlling tap the minimum size of the gooseneck between the service pipe and the tap shall be as follows:

SIZE OF TAP	SIZE OF SERVICE	MINIMUM SIZE OF GOOSENECK
inches	*inches*	*inches*
⅜	1	¾
⅝	1¼	1
¾	1	¾
¾	1¼	1
¾	1½	1¼
1	1¼	1
1	1½	1¼
1	2	1½
1½	2	1½
1½	2½	2
2	2½	2
2	3	2

In connections over 2 inches in diameter the gooseneck may be of the same diameter as the tap.

Size of service for domestic consumption. In buildings occupied for domestic purposes the minimum size service shall be regulated by the number of families supplied as follows:

NUMBER OF FAMILIES	MINIMUM SIZE SERVICE
	inches
1 and 2	¾
3 to 5	1
6 to 10	1¼
11 to 20	1½
21 to 30	2
31 to 45	2½

Multi-family buildings, housing families in excess of those listed above, shall be supplied with services in proportion.

Where the minimum size service for a specified number of families requires a tap in excess of that granted on the floor area basis for unmetered premises, the regulation relating to minimum size services shall supersede that of the floor area basis.

Meters. Water superintendents and engineers are coming to the conclusion that the past practice has resulted in too large meters being furnished in many cases. In This Journal, Vol. 6, page 26, March, 1919, Wm. R. Edwards gives the following general rule for residential property, which has been set up by the private water companies with which he is connected.

SIZE OF METER	NUMBER OF FAMILIES TO BE SUPPLIED
inches	
$\frac{5}{8}$	Up to 6
$\frac{3}{4}$	6 to 12
1	12 to 18
$1\frac{1}{2}$	18 to 30

The prevailing pressures in the territory when this rule is applied successfully are from 40 to 50 pounds. Mr. Saville in his paper on meters also refers to the relatively small meters that may be used on multiple family houses.

If a meter is larger than necessary there will be under registration of small flows. The very small flows may not be registered at all. It seems safe to say that the smallest size meter that will give adequate service to a premise is the one that should be used. The New York rules are again quoted for discussion.

Minimum and maximum size. The meter may be either the same size or one size smaller or larger than the tap controlling the service on which the meter is placed.

Shut-off. In any premises where water may be obtained through more than one metered service, the department reserves the right to shut off and seal any service.

CONCLUSION

The committee believes that many statements have been made in this report that will excite interest and some that may be strongly criticised. It desires to draw out the experience of the members, including their criticism, and trusts that many will add to the knowledge now available by stating the practice known to them on the vital parts of the delivery system which have been discussed herein.

SOME EXPERIENCES WITH WATER METERS AT GREENEVILLE, TENNESSEE

By J. W. McAmis[1]

The superintendent of water works is many times confronted with the necessity for deciding on the general policy to be pursued by his particular plant. He does not always possess the information necessary for a fairly accurate prediction as to the ultimate result to be hoped for by the adoption of the particular policy which he is considering.

Water boards and city councils, who generally receive little or nothing for the time and attention given to such matters, should hardly be expected to give these problems the detailed study necessary to arrive at the true solution.

It becomes the duty of the superintendent, therefore, to study the experience of others, in the light of conditions existing in his own plant, and to gather and present to the board or council such information and data as have a direct bearing on the subject in hand and would enable them to decide, quickly and wisely, the best course to pursue.

One of the outstanding situations to which the above remarks apply would be the extent to which meters might be wisely used. It is due to the realization of the far reaching results that may be obtained, by the proper handling of this matter, and to a desire to assist water works operators to the correct solution that this discussion has been attempted.

It cannot be truly said that all water plants should adopt a policy of universal metering and, by the same token, it would be difficult to imagine a water plant so fortunate that it could not use at least some meters to advantage.

We, in Greeneville, have been able to realize quite handsomely on our present investment in meters as will be shown in the following paragraphs.

[1] Superintendent, the Water Commission, Greeneville, Tenn.

The plant in Greeneville is about 30 years old and a small number of meters have probably been in service for 15 to 18 years. The first record of any extensive purchase of meters occurs in 1918, when sufficient purchases were made to bring the percentage of services metered up to about 10. Through the two year period following, the system was probably kept on about that basis and was slightly in excess of that at the beginning of 1921.

Mild water shortages were felt almost every year and, in 1919, a serious period of shortage occurred during the late summer to early winter, and the city employed an engineer to investigate and recommend the best course to pursue.

In accordance with his recommendations, an election was held and the voters authorized the issue of bonds to obtain funds for the building of a force main and electric transmission line to another large spring about two miles from the city, together with necessary works at the spring, the idea being to augment the present supply, which is also obtained from a spring.

The price of cast iron pipe became so high, however, before the work was started that it was considered wise to postpone the work at least until the next year. About this time (spring of 1920), Greeneville was visited by a serious epidemic of typhoid, which has been described in this Journal, March, 1921, p. 132, and the State Board of Health insisted that, if the use of the present water was to be continued, steps should be taken at once to provide for filtration.

It might be stated here that the water plant is handled separately from the city government, by three commissioners, elected one bi-annually for a term of six years, which, in this case, has proven to be an excellent arrangement, for the complexion of the commission cannot be suddenly changed, as would be the case if all were elected at one time.

The commission and the board of aldermen then agreed that, as the proposed extensions would provide little if any improvement from a sanitary point of view, it would be best to abandon the idea for the time being and to call a new election to provide enough funds for a filter plant. This action left the water shortage problem still to be solved.

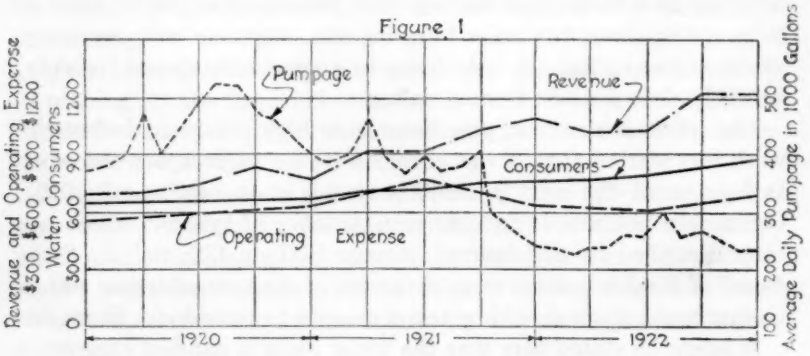
The water commission, which has no authority to borrow money for any purpose, then requested the board to borrow a sum sufficient to purchase meters for all services having sewer connections, since it was known that the flow of sewage greatly exceeded the amount

that would be expected from the number and nature of the existing connections. From personal inspections made by the present writer, who was employed June 1st, 1920, it was established that the greater part of water was being wasted through the sewers.

The request for funds was refused by the board, one member of which was himself one of the worst offenders in this respect. The water commission then began to seek other means of financing the purchase of meters, as immediate action was necessary, if another period of water shortage was to be avoided.

Meter manufacturers were willing at times to extend liberal terms for the payment of the purchase price of meters, but the commission hesitated to assume any extensive obligations, because in the past the water charges had been reduced in many cases, by the installation

Figure 1



of meters, and it could not be confidently predicted that the revenues would be sufficient to meet operating expenses and to provide an excess to pay for the meters.

The writer, however, pointed out that, in the past, a substantial sum had been expended each year for extensions to the mains to supply new consumers, and, if necessary, this work could be curtailed or deferred altogether until the meters were paid for.

He also urged that a contract be made for as large a number as was possible in order to benefit by the reduced price on the larger quantities. A contract was finally awarded for 500 $\frac{5}{8}$ inch meters, or their equivalent cost in larger sizes. An order was placed for immediate shipment of 100 $\frac{5}{8}$ inch meters and their installation was started about June 1, 1921. It soon developed that any fears regarding the effect that this policy might have on the gross revenue were unfounded as reference to figure 1 will show.

The meters were installed as fast as funds were available and little was paid the manufacturer until near the close of 1921. The gross revenue for 1921 exceeded that of the previous year by about $3,400.00 and provided ample funds for installation expenses and $700.00 for the meter company, which is an excellent showing, considering the size of the plant, the fact that flat rates are collected in advance, and each consumer passes one month without paying when the meter is installed.

Last year, 1922, the revenues were increased by almost as much ($3,200.00) with very little increase in operating expenses.

Again referring to figure 1, it may be seen that the average daily warer consumption was reduced from a maximum of 525,000 gallons for the months of August and September 1920 to 300,000 gallons per day in August, the maximum for 1922.

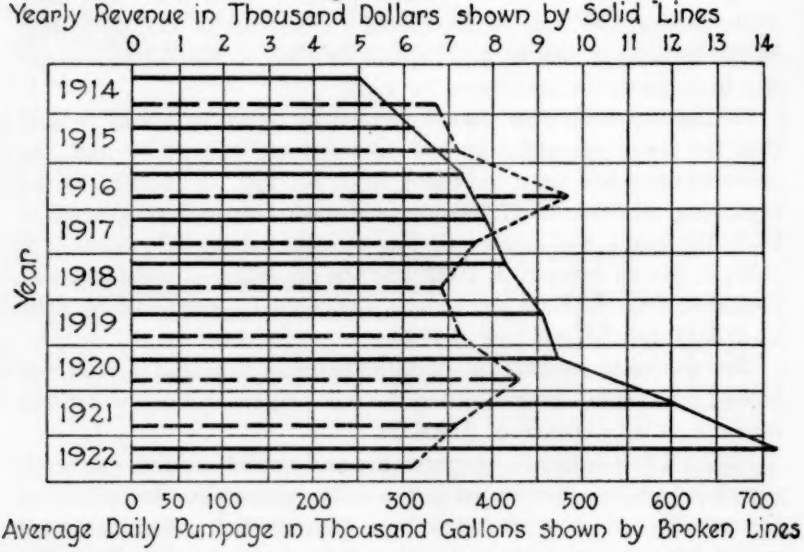
Taking the three year period covered by figure 1, it may be said that the water consumption has been reduced almost by half, the gross revenue has been increased from $700.00 per month, at the beginning of 1920, to $1,200.00 per month for the last quarter of 1922, the number of consumers has increased from 667, January 1, 1920, to 844 on January 1, 1923, and the operating expense has been increased from $590.00 per month, averaged for first half of 1920, to $710.00 for the last half of 1922.

The abnormal increase in operation expense indicated in 1921 was caused by a serious breakdown in the pumping machinery, which was repaired at an expense of $1400.00.

Figure 2 was originally prepared for and published in an operating report, which was distributed to the water patrons and tax payers of Greeneville. It is reproduced here to give the reader a longer period for comparison than is covered by figure 1, as it illustrates more forcibly the relation between past and present conditions. The revenue figure is shown as total yearly, in figure 2, and the water consumption is given as daily pumpage averaged for the year. The pumpage indicated for 1922 is incorrect, however, as the commission did not consider it wise to publish the exact figures, which are somewhat lower. This was done because the commission wishes to maintain a wider margin of safety between the maximum consumption and the minimum flow of the spring than has been the case in former years. It did not wish to convey the impression that this srping would suffice for any considerable length of time. Therefore. the figure represents the maximum for a few days in 1922.

The installation was continued until all water services having sewer connections were metered and we have found this an excellent stopping place, as the out-lying portions of the city are not yet provided with sewers and leakage is likely to annoy the consumer until he makes the repairs himself. If not, the repair man or meter reader would see it and steps would be taken to force the repairs in such cases. For those reasons, it would seem to be a useless expense, at least in this case, to meter services supplying only one opening, which may usually be seen from the street.

Figure 2



Several meters have been installed on such services and the consumption was so small, about 100 cu. ft. per month, that we have not considered it worth the cost.

In attempting to analyze the benefits and improved operating conditions resulting in Greeneville during the last three years, the greatest of these would seem to be the reduction in consumption, which has been accomplished without restricting, in any way, the legitimate use of water, and the fact that the expenditure of a sum of money for an additional supply, several times greater than the cost of the meters, has been deferred indefinitely. The 70 per cent increase in gross revenue has operated to put this department on its

feet, financially speaking, in that it has provided funds not only to defray the cost of purchasing and installing the meters, but has put it in a position to pay such portion of the sinking fund and interest charges as remain, after deducting for fire protection and the city's use of water.

After deducting from the 70 per cent increase in revenue, the proportional increase in the number of water consumers, which is 25 per cent, it would seem fair to consider that the remaining 45 per cent was largely due to the increase in percentage of services metered, which would be 55 per cent (metered at present) less 10 per cent metered at beginning of 1920, or an increase of 45 per cent.

In any attempt to estimate the benefits of meters likely to be realized in any given plant, in the light of experience at Greeneville, a vital consideration would be the relation between the flat rate and meter schedules. Those in use at Greeneville are given below:

Flat rates

Minimum charge 50¢
50¢ per month for first opening
25¢ per month for each additional

Meter schedule

Minimum charge $1.00
20¢ per 100 cu. ft. for first 2000
15¢ per 100 cu. ft. for next 3000
12½¢ per 100 cu. ft. for next 5000
10¢ per 100 cu. ft. for next 6000
7½¢ for all excess

These rates would probably not be suitable for use by any other city, but are given here for purposes of comparison only.

Taken by and large, it appears that the meters have been of great benefit to Greeneville and have resulted in a saving of actual dollars to the city as a whole, which should always be considered the chief criterion of merit in determining upon the adoption of any such policy as we have here discussed.

SECOND PROGRESS REPORT OF COMMITTEE ON PHYSICAL STANDARDS FOR DISTRIBUTION SYSTEMS[1]

The Committee has so far refrained from resorting to the general circulation of a questionnaire in the expectation that there would be a larger measure of voluntary response to the publication of its first progress report in this JOURNAL, January, 1923, than has been forthcoming.

A few interested individuals have responded and we have initiated communication with others, but we wish to register here another request for comment and suggestion from the many able men who are operating the large distribution systems of the country.

In particular, data and discussion on the various "Practical Details" are desired.

The following additional items of Terminology are offered:

7. *Distributing reservoir* is recommended rather than "Equalizing Reservoir" or "Service Reservoir." Equalization is the function of all reservoirs; and it is desirable to limit the use of the word "service" as far as possible to its universal general sense and its specific waterworks usage in "service connection."

8. *Zones.* A "zone" is an area situated between certain approximate limiting elevations served by an independent portion of the distribution system (language adapted from Turneaure and Russell, p. 769).

The several zones should be distinguished by numbering from the lowest to the highest, prefixing locality names also where necessary.

9. *Relay pumps* are those which draw water from the mains or reservoir of one zone and lift it to the elevation necessary for the service of a higher zone.

[1] This report has been prepared under the direction of Council. The personnel of this Committee is as follows: G. Gale Dixon, Chairman, Cleveland, O.; J. Arthur Jensen, Minneapolis, Minn.; E. E. Lanpher, Pittsburgh, Pa.; V. Bernard Siems, Baltimore, Md.; W. Z. Smith, Atlanta, Ga.; L. Chivvis, St. Louis, Mo.; C. E. Davis, Memphis, Tenn.; and J. R. McClintock, Kansas City, Mo.

STANDARD HOSE THREADS

The Standardization Council referred to this Committee a question raised by the Canadian Section of the Association regarding the advisability of adopting for Canada a standard hose coupling of five threads to the inch instead of the present American standard of seven and one-half threads. The matter was given considerable attention at the annual meeting of the Canadian Section in Brantford, Ontario, on May 12 and 13 following a paper by Norman M. R. Wilson, Chief Engineer of the Brantford Water Works. (This JOURNAL, January, 1923.)

The Canadian Section furnished us with copies of the original paper and of the discussion which followed it, and the conclusions of our Committee were unanimous as follows:

1. The use of five threads to the inch rather than seven and one-half has merit in avoidance of cross-threading and in being more rapidly cleared of dirt or ice, but the advantages are not considered to be of sufficient importance to warrant consideration of a change in the American standard, with all of its attending cost and confusion.

2. There are obvious advantages in having the same standard in Canada as in the United States, especially for the border towns.

PROGRESS REPORT OF COMMITTEE ON PRACTICABLE LOADINGS FOR PURIFICATION PROCESSES[1]

The Committee on Practicable Loadings for Purification Processes had hoped to present a report embodying some conclusions drawn from the tabulation and study of data collected from numerous water purification plants throughout the United States, but, because of the character and volume of the information in the hands of the members of the Committee and at their disposal, it is believed that any conclusions formulated now would be premature and possibly misleading. Therefore the Committee can only present a summary of the work done by the individual members of the Committee, the character and extent of the information obtained from various places, the investigations and studies pertinent to the work of this Committee, now being carried on through various agencies, and such suggestions as to the adoption of standard methods and processes as are plainly seen to be advisable at this stage of the Committee's work.

In May, 1921, a questionnaire was sent out to a large number of filter plants throughout the country by the members of the Committee, which brought to them a quantity of information, most of which, however, was of little value for the purposes of the Committee, on account of the great majority of plants being operated under average conditions and treating waters not relatively high in pollution. The data collected from each plant showed so much variation from time to time because of prevailing conditions (e.g., the variations in quality of the raw water, such as turbidity, fineness of suspended matter, color, hardness, temperature and bacterial content, quantity of water treated, length of time for coagulation and sedimentation, rate of filtration, etc.), that it seemed an interminable and hopeless task to attempt to determine limits for purification modified by minimum or maximum requirements of these numerous variables.

[1] This report has been prepared under the direction of Council to facilitate discussion by members of the Association of material secured by the Committee, the personnel of which is as follows: Edward E. Wall, Chairman, St. Louis, Mo.; Charles G. Hyde, Berkeley, Cal.; Seth M. Van Loan, Philadelphia, Pa.; Richard Messer, Richmond, Va.; and F. H. Waring, Columbus, Ohio.

It was the intention of the Committee to select from the list of plants answering the questionnaire, those operated by experienced men, and dealing with raw waters having rather a wide range in their objectionable qualities, for close observation and study.

This did not prove to be entirely practicable when the information received from numerous places was tabulated, because of the great variation in the character of purification plants, the diversity of the methods used and the degree of skill exercised in their operation, not to mention the wide range in the characteristics of the waters treated, so that the selection of distinctive plants was not so easy as had been at first imagined.

To illustrate this, and also to give an idea of the ranges in the qualities of the raw waters and the variations in treatment and operation, the attached table summarizing results, has been prepared.

An examination of the individual reports reveals the fact that many plants deal with raw water varying in one or more of the objectionable characteristics from the maximum to the minimum shown in the table, and are reported as obtaining satisfactory results. This may be interpreted as meaning that the consumers in those localities, having always been accustomed to the local water supply, have become resigned to it, believing that no further improvement is necessary or may be made. The Committee has no way of finding out where this is the case, as only at a few places are complete and thorough analyses made frequently enough to supply the information necessary to establish the real quality of the water supplied to these communities.

The figures set out in the table 1 give but an imperfect idea of the difficulty of attempting to classify purification plants according to the quality of the raw water treated. Leaving out of consideration the wide variance in methods of treatment, there still remains for study the great differences between the surface waters east of the Alleghanies and those of the Mississippi river valley, as well as the variations in the individual waters of any district of considerable area. For example, of the nineteen plants in Illinois summarized in the table, none of them take their supply from Lake Michigan, but from streams, the waters of which would naturally be supposed to be similar in character. Now, as to the loadings on these plants, the maximum turbidity reported at any one plant is 15,000; two plants report maxima of 10,000; one reports 8000, and several 2500. Two plants report average turbidities of about 500, two others from 250 to 300, and four from 100 to 150.

TABLE 1

STATE	NUMBER OF PLANTS	TYPE OF PLANT	RAW WATER							TREATMENT OF WATER BEFORE FILTRATION	RATE OF FILTRATION PER ACRE	TIME BETWEEN WASHINGS	CHEMICALS USED
			Turbidity		Color		Bacteria per cubic centimeter						
			Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	B. coli per 100 cc. average				
											m.g.d.	*hours*	
Pennsylvania..	6	Rapid sand	6,000	2	500	5	17,000	5	15- 1,000	Aeration, coagulation and sedimentation	80-176	3-50	Alum, iron, soda ash and chlorine
New York.....	6	Rapid sand	6,000	13	180	6	100,000	14	15-340	Coagulation and sedimentation	120-181	4-24	Alum, chlorine and copper sulphate
New Jersey....	3	Rapid sand	1,000	5	150	5	2,400	0		Coagulation and sedimentation	62-200	8-60	Alum
Missouri..	5	Rapid sand	5,000	5	35	3	113,000	15	22-90	Coagulation and sedimentation	62-125	10-171	Alum, lime and iron
Illinois.....	19	Rapid sand	15,000	5	250	8	90,000	40	20-520	Aeration, coagulation and sedimentation	50-175	6-72	Alum, lime and soda ash
Pennsylvania..	5	Slow sand	4,500	2	40	5	1,200,000	110	75	Sedimentation aeration and pre-filtration	2-10		Alum, lime and chlorine
New York	3	Slow sand	600	3	62	15	48,000	10	1,000-13,000	Coagulation sedimentation and pre-filtration	3		Alum and chlorine

The maximum color reported is 250; two plants report 70, four give maxima of 50 and seven state their highest figures from 30 to 40. The highest average color reported is 54, two plants give averages of about 35, four others from 25 to 30, and five from 15 to 20.

The maximum bacterial count is 90,000, the next 50,000, three others report 18,000 to 24,000 and two plants 8500. The highest average is 3600, two plants have 2100, two others 1250 and 1750 respectively, and four from 400 to 800.

Two places report gas-forming organisms present in all 0.1 cc. samples of raw water, two others find positive results only in a majority of 0.1 cc. samples. Eleven plants report that 10 cc. samples of raw water always show positive results and that the 1 cc. samples in most cases also analyze as positive. Three places report 0.9, three others 0.75, and four that 0.05 cc. samples show positive results.

All of these plants are reported to purify successfully these waters, which vary so greatly in their objectionable qualities, but it is likely also that there is just as great a variation in the quantities of chemicals used and in the wash water and chlorine necessary to produce safe effluents.

Information on the Illinois purification plants was supplied to the Committee by Mr. Harry F. Ferguson, Chief Sanitary Engineer of the State Department of Public Health, who has generously agreed to digest the present available analytical data along the lines decided upon by the Committee and to arrange for additional and more complete analytical data in the future from plants dealing with highly polluted or difficult waters.

There are not many water purification plants in Missouri, and information has been received from only five places, at none of which is there any indication of overloading, nor do any of them deal with waters carrying a high degree of pollution. This is true of all the plants in several other States, for example, Iowa, Minnesota, Wisconsin, North and South Dakota, from which the Committee has received data. Inquiries as to whether the communities in these States are satisfied with the water supplied them is invariably answered in the affirmative. Requests for health statistics on water-borne diseases have been barren of results, principally because no reliable records seem to be available. All of these plants seem to be operating without changes in the methods of treatment, year after year, so that apparently the raw water is not getting appreciably worse.

There are 52 filtration plants in Virginia, of which one is of the slow sand type, and four are primarily for water softening. None of the raw waters treated are badly polluted and the turbidities seldom exceed 2000 or 3000 and then only for short periods. Very little data are available as to what should be considered excessive loads for the several processes, such as coagulation basins, filters and sterilization. Practically all of them are being operated without serious difficulty and the loads on basins and filters are well within the range as to what should be considered permissible. Only eight of these plants have laboratory facilities at the works, and these may be classified with regard to the kind of water treated, as follows:

NUMBER	TOTAL CAPACITY	CLASSIFICATION
	m.g.d.	
3	48	Primarily for color removal. Bacterial pollution negligible
1	6	Treating impounded supply slightly turbid at times. Bacterial pollution negligible
2	8	Bacteria (37°C. count) seldom above 1000 per cubic centimeter. Turbidity usually below 600
1	28	Bacteria (37°C. count) from 500 to 3000 per cubic centimeter and turbidity usually below 1000. Only partial laboratory data available
1	30	Richmond plant, filtration contemplated

From studies on the above plants, and also from observations at the smaller plants, Mr. Richard Messer, Chief Engineer of the State Board of Health of Virginia, and a member of this Committee, draws the following tentative conclusions:

1. Coagulation Basins. (*a*) For colored waters the period should be at least 6 hours and preferably longer, up to 10 or 12 hours.

(*b*) For turbid waters, the period should be at least 3 hours. However, a longer period serves as an extra safeguard at times of sudden fluctuations in the character of the raw water.

(*c*) The velocity of flow through the basin should not exceed 0.75 feet per minute and in the last half of the basin a velocity of not over 0.4 feet per minute is desirable.

2. Coagulation. Regulation of the application of chemicals to obtain the optimun coagulation is a matter of prime importance. When the optimum coagulation is obtained the floc which goes onto the filters will be of such quality as to maintain maximum efficiency of the filtration process, provided the floc is not broken up while being conveyed from the basin to the filters. If

the application of chemicals is not correct the suspended matter carried onto the filters will be of such a character as to penetrate deep into the sand and eventually pass all the way through. Except as to the amount of wash water required it does not make so much difference as to the *quantity* of floc carried onto the filters, but the *quality* is of prime importance.

3. Filter Sand. For filtering waters in this state, the sand should have an effective size of between 0.35 and 0.45 mm. and a uniformity coefficient of not greater than 1.6. Not more than 10 per cent by weight shall be coarser than 0.9 mm.

4. Filter Gravel. The depth of gravel shall be not less than 18 inches and preferably 20 and 21 inches. The gravel shall be graded and placed carefully and the thickness of layers shall vary directly as the size; i.e. the greatest depth to consist of the 2½ to 1-inch size and the thickness of layers decreasing up to the surface layer.

5. Washing. For effective washing the rise should not be less than 18 inches per minute and preferably 24 inches per minute, but not greater. It is important that the rate shall be uniform over the entire bed.

6. Chlorination. Provision should always be made for sterilizing the filtered effluent with chlorine as a secondary safeguard.

In some instances chlorination alone may be relied upon, provided the supply to be treated is practically free from turbidity at all times and provided further that the sanitary survey shows that there is only a remote possibility of sewage getting into the supply, but where the origin of the B. coli content cannot be ascertained.

The waters treated in the northeastern states, Pennsylvania, New York, New Jersey, etc., are in many cases highly polluted, so that it is a far more promising field for study for the purposes of this Committee than may be found in the southern and western states.

Mr. S. M. Van Loan, Deputy Director of the Bureau of Water in Philadelphia and a member of this Committee, has collected a mass of data from these states, but like the other members of the Committee, has met with great difficulty in obtaining precise and definite information on points of special interest to supplement data given in the first reports. In many cases members of the Committee have been greatly disappointed in receiving no replies at all to questionnaires sent out, and especially from plants known to be treating difficult waters. The Committee wishes particularly to emphasize the fact that it is entirely dependent on the assistance and co-operation of water works and health department officials in general, and the Committee feels especially at liberty to call upon members of the American Water Works Association for assistance and to expect prompt and generous response from them.

Mr. Van Loan goes on to say that due recognition is given to the fact that, at certain plants, methods of keeping records are widely different and a questionnaire might not at all times adapt itself for furnishing the information desired. One feature that has injected a degree of uncertainty in analyzing plant results is the method used in determining bacterial counts, and, until the Council on Standardization has set a standard, which will be used generally throughout the country, there can be no consistent comparison made on the various plant results. He suggests that a standard form for reporting filter operation should be adopted.

Following his appointment on the committee of the American Water Works Association on Practicable Loadings for Purification Processes in 1920, Mr. F. H. Waring, Principal Assistant Engineer, Ohio State Department of Health, organized the Ohio Conference on Water Purification in November, 1921, comprising the men actually employed in charge of water purification plant operation in the state of Ohio. Ohio has 62 water purification plants serving 32 cities, 23 villages and 7 unincorporated communities. The total population thus served is 2,561,000 as of the 1920 census. A practically complete representation was obtained at meetings held in Columbus in November 1921 and November 1922.

At the 1921 meeting questions were put to the Ohio filter plant superintendents, these questions involving research study upon loading of water purification processes. The writer selected 10 filter plants for the conducting of the special studies. The selection was based on an accurate knowledge of the peculiarities of the water purification plant, the raw water and at the same time these plants were in charge of experts trained and experienced in water purification and control. The variety of conditions encountered is indicated as follows: *Akron* a 30 million gallon plant taking water from a large impounding reservoir on Cuyahoga River; *Cincinnati* a 112 million gallon plant taking water from Ohio River directly; *Cleveland* a 150 million gallon plant taking water from Lake Erie; *Ironton* a 4 million gallon plant taking water from Ohio River directly; *Lima* an 8 million gallon plant using as a source of supply a large artificial lake receiving intermittent pumpage from Ottawa River; *Portsmouth* an 8 million gallon plant taking water from Ohio River directly; *Sandusky* a 10 million gallon plant using as a source of supply Sandusky Bay of Lake Erie; *Steubenville* a 6 million gallon plant using Ohio River as a source of supply; *Toledo* a 56 million gallon plant using Maumee

River as a source of supply; *Warren* an 8 million gallon plant using Mahoning River as a source of supply. In addition to the above, three plants having water softening features were selected, *Columbus* a 54 million gallon plant using a large impounded reservoir on Scioto River; *Defiance* a 2 million gallon plant using Maumee River directly; *Youngstown* a 28 million gallon plant using Mahoning River as a source of supply.

The foregoing selection served to cover the range of raw waters in this state varying from the least polluted and cleanest source of supply (Lake Erie at Cleveland) to the most intensely polluted and otherwise objectionable source of supply (Mahoning River at Youngstown).

In order to make comparisons of the several plants the 1921 conference standardized the procedure for reporting; for laboratory practice; and quality of the filter effluent both before and after chlorination. In several instances it was possible to utilize previous data collected, but for most plants work was initiated. The 1922 conference held at Columbus in November took up the topics assigned previously, each of the ten regular filter plants reporting upon the studies and each superintendent offering opinions in answer to the questions. Certain of the topics have been held over for further study and certain new questions were raised. The complete discussions of these topics and including original papers of great value prepared by some of the men are now being compiled for publication in a special bulletin of some 125 pages to be published in April by the Ohio State Department of Health.

There will be available for the Committee the results of investigations into the stream flow, the pollution and the self-purification of the Illinois River, conducted by the United States Public Health Service, and of a similar investigation on the Kansas River and its tributaries conducted by the State Board of Health of Kansas, whose Chief Engineer, Mr. Albert H. Jewell, writes that, on account of the mass of data to be digested, no information of value to the Committee may be given at present.

The determination of the practicable loads for purification processes leads directly to consideration of the pollution of sources of water supplies and the self-purification of streams and impounded polluted water, so that study of these subjects must perforce become a part of the Committee's work. Even if it were possible to develop the science of water purification to the point where water fit for human

consumption might be produced from the worst polluted sources, the item of cost, if nothing else, would set a limit beyond which it would be impracticable to go,—that is, there would always be a point where the cost of treatment would mount up to such a figure that the prevention of pollution would be cheaper and more practicable than purification.

In this connection, Mr. H. W. Streeter, Sanitary Engineer of the United States Public Health Service, writes from Cincinnati:

> In connection with stream pollution investigations being conducted by the U. S. Public Health Service, consideration is being given to a proposed extension of a preliminary study of filter plant loading factors made by this service a few years ago, the results of which were briefly summarized in a paper, "The Loading of Filter Plants," appearing in the March, 1922, issue of the Journal of the American Water Works Association.
>
> Consideration has thus far been given to two possible lines of study of the problem, one consisting of a field survey of a selected group of plants in routine operation, and the other an experimental study of loading factors under controlled conditions, using for this purpose an experimental plant to be built, somewhat similar to those which were recently operated at Milwaukee and Detroit, but located on the Ohio River at Cincinnati, which is our headquarters. We have thought of the latter kind of a study as permitting us to observe purification efficiencies under conditions approaching or even surpassing overload without incurring the dangers to water consumers such as would be the case if experiments of this kind were to be attempted at a regular plant.
>
> The experimental method would permit us, moreover, to adjust arbitrarily and measure accurately the various complex factors that modify purification efficiencies under different conditions: likewise to determine under controlled conditions whether any definite law underlies the reaction of water purification processes to different degrees of loading. Enlightened on these points, we could then test their generality by field survey data and greatly clarify the main objective to be sought in such a survey.

The Committee is much interested in Mr. Streeter's project and will follow closely the establishment and work of this experimental plant, co-operating with him in every possible way.

Although it may seem that the Committee has little to show for the work of almost two years of its existence, in truth a great deal of work has been done in collecting information, finding out what sort of facts may be obtained and used, in determining the general course of investigation, and obtaining assistance from and co-operation with individuals and with public and private organizations.

The Committee has also come to a full realization of the formidable task before it, the many directions in which its inquiries must lead and the great variety of perplexing problems resulting therefrom.

The individual members of the Committee are, to a certain extent, working independently of each other, each one following largely his own ideas as to how information should be obtained and digested. Then each member will send to the chairman a statement of conditions and results as he finds them, together with his opinions and conclusions. The chairman will broadcast them to the rest of the Committee and to such others as are assisting the Committee, and will eventually combine all these reports into one general Committee report.

As has been heretofore stated, satisfactory service to the people served, and vital statistics not below the average for such places, must be considered conclusive evidence that water purification there is efficient. The loads upon these plants, if unusual, may serve to mark the approach to limitations in general. Any plant may, for a short time, be taxed to the full extent of its capacity and require all the ingenuity of its superintendent and chemist, together with a liberal use of chemicals, to deliver a potable and safe water under these extreme conditions, but this load should hardly be taken as the limit for similar purification plants, for at least two reasons, first, because it is extremely improbable that any other plant could encounter even approximately the exact conditions, and, secondly, because the peak load under which the plant was able to stand up for a short time was an overload and beyond its working limit.

A general standard may be set for a safe water for domestic use, just as that established by the United States Treasury Department for waters used by common carriers, but any attempt to place a limit on color, hardness, taste, odor, etc., would seem to be futile, since these characteristics vary with localities, where each community sets up its own standards.

During the next year, considerable progress should be made in the studies and investigations under way and referred to in this report, so that your Committee will be in a better position at the next annual convention to make definite recommendations and to set forth some general principles.

David Augustus Decrow

February 15, 1922

David Augustus Decrow, who died in East Orange on Thursday, February 15, was buried in Lockport, New York, Sunday afternoon, February 18.

Born in Bangor, Maine, a descendant of Vere Royce, a distinguished New England Civil Engineer, from whom Mt. Royce received its name, he graduated from Maine State College of Mechanic Arts of the University of Maine at Orona, in the class of 1879. While in College he was prominent in athletics and pitcher of the baseball team, being one of the first curved ball pitchers.

After graduation from college, Mr. Decrow taught school for a year or more in a lumber camp in Maine, but was forced to give up that work due to lack of funds in the school board treasury.

He went from Maine to Lockport in the early '80s and became associated with the Holly Manufacturing Co., as a mechanical draftsman. Here his engineering and business ability were evident from the start and his promotions with the Holly Co. were rapid. In 1893, he was made Designing Engineer, in 1900, Chief Engineer and in 1903, Secretary of the Holly Manufacturing Co. During his connection with that plant he became known as a waterworks engineer of national prominence and continued his work as a specialist in that line to the time of his death.

Mr. Decrow designed and installed waterworks pumping machinery for many of the largest cities in the United States, among the most prominent of which are:

Buffalo, N. Y.	Cincinnati, O.
Detroit, Mich.	Louisville, Ky.
St. Louis, Mo.	Boston, Mass.
Columbus, O.	Cleveland, O.

Philadelphia, Pa.

Some years ago the Holly Manufacturing Company was combined with the Snow Steam Pump Works at Buffalo, New York, as part of the International Steam Pump Company. Mr. Decrow came to Buffalo at the time of this change and took charge of the Pumping Machinery manufactured by both companies.

The International Steam Pump Co. was succeeded by the Worthington Pump and Machinery Corporation in April, 1916. Soon thereafter Mr. Decrow was called to the head office in New York as manager of the Waterworks Department and continued in this position until his untimely death. It is significant that he remained with what was to all intents and purposes the same organization from the time he began his professional work until the close of a most successful career.

Mr. Decrow was active in the affairs of the American Society of Mechanical Engineers and chairman of the Committee for the Revision of Test Code for Reciprocating Displacement Pumps. He had been President of the Buffalo Club, President of the Park Club at Buffalo, Member of the Buffalo Consistory and Ismailia Temple of the Mystic Shrine and Beta Theta Pi College Fraternity.

He had a wide acquaintance and has left behind him a record of constructive professional accomplishments which will serve as an inspiration to those who follow him. He is survived by his wife and two sons.

DISCUSSIONS

TASTES AND ODORS

At the meeting of this Association, May 1922, there was an excellent discussion of tastes and odors in public water supplies filtered by different processes. Many different phases of this subject were discussed by the speakers. Several of these have been covered by publication of parts of the discussions in the JOURNAL.

One of the most interesting and important phases of the discussion, not covered by the published papers, is the effect of the oxidizing power of the filters upon tastes and odors.

In the slow sand filters, operated at a rate that is not too high, there is an oxidizing action which results in the burning up and destruction of many kinds of organic matter. Some of the substances that produce tastes and odors are removed in this way. The free and albuminoid ammonias give, perhaps, the best index to the amount of organic matter and to its removal by nitrification in filters.

This action of nitrification is biological and depends upon the growth of organisms of certain kinds in the sand of the filter. The processes of nitrification were studied at the Lawrence Experiment Station of the Massachusetts State Board of Health, and elsewhere, years ago and they are well understood.

Mechanical filters operating at higher rates do not afford opportunities for much, if any, nitrification.

In the course of the discussion at Philadelphia, where the chemists and other competent representatives of most of the major water purification plants in the United States were present, inquiries were put as to experiences with tastes and odors, and there is a stenographer's report of their answers. This record was supplemented by inquiries by letter to a number of important plants not reported in this discussion.

A complete and adequate statement of the results of this discussion would require not only a statement of the experiences in each case, but also a statement in regard to the source and character of the raw water and the extent and kind of purification works. The writer will not attempt to go into these details. He simply records his

personal impression, as a result of careful attention to the data so made available, that the slow sand filter plants, affording an opportunity for nitrification of the less stable organic matters, have given much less trouble with tastes and odors, than have corresponding mechanical and rapid sand filters in which there is little if no nitrification.

There are no doubt some materials that cause tastes and odors that are so stable and resistant to oxidation that they resist nitrification and pass through any filters that can be used. It is not to be expected that water filtered even by slow sand filters will be entirely free from the tastes and odors of the raw water. The evidence gathered in this discussion seemed to be clear cut and definite that, where there was an opportunity for nitrification in the filters, the taste and odor problem is far less troublesome than where there was no such opportunity.

Years ago free and albuminoid ammonia used to be determined as a matter of laboratory routine in all sanitary water analyses. As the years have gone by increasing importance has been attached to other things and the ammonias are now determined at only a few filter plants. Howard's results at Toronto and occasional results at other plants show that the sand filters eliminate nearly all of the free ammonia. In this respect they check up and correspond with the evidence at Lawrence, Massachusetts, where the Merrimack River Water, containing much material of this kind, has been filtered for the last thirty years.

It is the writers impression that the free ammonia is perhaps the best available index of certain kinds of odor producing substances, and, from this standpoint, it is unfortunate that the ammonia determination has fallen into such general disuse.

ALLEN HAZEN.[1]

INDUSTRIAL WASTES AND WATER SUPPLIES

In view of the trend of the discussion on industrial wastes[2] towards existing laws applicable to this problem, I shall confine my remarks to the situation as it exists today in Pennsylvania.

You may readily appreciate from the report of the Committee[2] that we have a real problem in Pennsylvania. As a matter of fact,

[1] Consulting Engineer, New York, N. Y.

[2] This Journal, page 415.

138 water supplies have in the past been affected by wastes of various kinds. Of these by far the greater number have been affected because of drainage from coal mines and washeries. These are 96 in number, with 15 supplies affected by wastes from by-product coke ovens coming next in number. The remaining 37 supplies, in varying numbers, have been troubled by discharges from wood distillation plants, oil refineries, tanneries, metal working plants, gas works, textile concerns, pulp mills, and by oil pipe leakage and flow from oil wells. This will give some idea of the diversity of the problem.

There are several governmental agencies in Pennsylvania that have to do with water supplies in one form or another; the Secretary of the Commonwealth, who is concerned with charters only; the Water Supply Commission, handling matters of conservation, distribution, dams, stream encroachments and charters; the Public Service Commission, taking up questions of charters, valuations rates, adequacy of service, in a word, as a public utility; the Department of Fisheries, whose chief concern is in matters relating to the propogation, distribution and protection of fish life; and finally the Health Department, exercising jurisdiction in questions of water supply as affecting the public health.

The Department of Fisheries has a law relating to stream pollution. This was passed in 1917 and prohibits the discharge into State waters of substances of any kind or character deleterious, destructive or poisonous to fish. For violations a fine of $100.00 is provided. Convictions have been secured under this act, and the fine collected, but the law lacks teeth, a fact admitted by the Fish Commissioner himself, and is not accomplishing much.

The Health Department was created in 1905. Its head is a Commissioner, who must be a physician. There is a Deputy Commissioner and an Advisory Board, as well as the various Divisions handling specific phases of the work. The Purity of Waters Act, so-called, defines what constitutes the "Waters of the State" and also governs questions relating to sewage discharge therein. In the Act of Assembly creating the Department, the Commissioner of Health is given power to handle nuisances. The Advisory Board is empowered to establish regulations, which after being properly promulgated, have the force of law, and in 1920 the Board did set up a regulation relating to the discharge of deleterious matters into waters of the State. This regulation covers slaughter houses, rendering works, depositories for dead animals, glue works, tanneries, wool-

washing establishments, paper mills, by-product coke ovens, dye works, oil refineries, dairies, creameries, cheese factories, milk stations or similar establishments. In all the laws and regulations, however, it must be shown that the substances discharged are detrimental to public health, which is a difficult matter often to prove. As stated by Mr. Fuller and by Mr. McCaleb, the Pennsylvania laws carry a distinct exemption of coal mine drainage and tannery wastes, two of our most vexing problems. At least that is true of the former.

The foregoing facts are presented to indicate the conditions existing in Pennsylvania and to emphasize the seriousness of the situation as well as the lack of adequate legislation to deal with these problems. Pennsylvania probably is typical of many of the other states in this respect.

H. E. Moses.[3]

CLARK AND LUBS BUFFER STANDARDS

Hatfield suggests a substitute method for pH determination for that of Clark and Lubs, to be used particularly in the smaller plants where good laboratory facilities are not obtainable.[4] If the Clark and Lubs standards are prepared in pyrex glass tubes, drawn to a point and sealed, the colors will fade very little even after a year's use.[5] It is possible to purchase these color standards ready for use and to purchase the buffer solutions without the addition of dye. To check the color standards at systematic intervals, it is only necessary to pipette the required amount of buffer, add the dye solution and compare. Since these buffer solutions, without color do not deteriorate, even after a year's standing in pyrex glass, no additional equipment or special skill is required to keep the standards correct. It is conceded that the Clark and Lubs buffers have been generally adopted as standards, but the ease of manipulation in the hands of the man not trained as a chemist is not yet generally recognized or sufficiently emphasized.

Edward S. Hopkins.[6]

[3] Assistant Chief Engineer, State Department of Health, Harrisburg, Pa.
[4] Hatfield, Journal, March, 1923, page 298.
[5] Baylis, Journal, September, 1922, page 802.
[6] Chemist, Water Department, Baltimore, Md.

SOCIETY AFFAIRS

CANADIAN SECTION

Registration opened at the Carls-Rite Hotel on February 22, 1923, in Toronto. The total registration amounted to something over one hundred and thirty, but does not include the names of the members of the Engineer's Institute, who attended the Thursday evening session.

According to the program it was intended to open the session with a discussion on, "Hose Connections for Fire Hydrants," but, owing to the unavoidable absence of the Chairman of this Committee, discussion was left over for the Annual Meeting to be held in May. As the members appeared to be interested in the manufacturer's exhibit, it was decided to postpone the other items appearing on the program for the morning session and formally to open the meeting at the luncheon held at 12:30 p.m.

The luncheon, attended by all the members and guests present, was presided over by Mr. R. L. Dobbin, the Chairman, who called upon Mr. R. C. Harris, Works Commissioner of Toronto, to address the members present. Mr. Harris welcomed the visitors to Toronto on behalf of Mayor Maguire, who, while unable to be present at this time, promised to attend later in the day. Mr. Harris spoke of the work of the Canadian Section and its efforts to claim the interest of the water works men in the smaller towns. He pointed out the advantages which membership in the Association brought and the opportunity of personal contact with engineers and others who are recognized authorities in the water works profession. He prophesied greater expansion for the Canadian Section and stated that the attendance, the manufacturer's exhibit, and the papers to be presented were good evidence of the interest taken, not only by the Executive, but by the water works men generally in the Association.

Mr. J. M. Diven, General Secretary of the American Water Works Association, in his remarks outlined briefly the history of water works since the formation of the Association. In speaking of this meeting he said that in every respect it was the best sectional meeting he had

ever attended. This was particularly gratifying to him, as he had come to look upon the Canadian Section as his pet. He told of the Association's efforts to standardize methods and materials both in actual construction work and in office administration. He urged every one to attend the meetings of the Sections and extended a special invitation to all to come to Detroit, May 1923, for the Convention.

Mr. Alexander Milne, St. Catherines, offered congratulations to the Executive for the success of the present meeting. As one of those who organized the Canadian Section, he recalled the feeling of pessimism which pervaded that first meeting when the organization of the Section was undertaken. He felt that the enthusiasm of the present meeting was an ample and glorious reward for himself and others, who believed that the field was large and the opportunities many for a Canadian Section.

Chairman Dobbin announced some changes in the program and invited all to attend the evening session for this day, which would be followed by a smoker. He then asked all to adjourn to the Convention hall for the reading and discussion of papers.

At 2:30 p.m., Professor R. W. Angus, Toronto University, gave an illustrated address on, "Water Works Intakes," which was followed by discussion.

"Connections for Auxiliary Fire Protection," on the program for the morning session, was now taken up. This discussion brought out the fact that F. M. check valves were being substituted for the metal-to-metal check which had been specified in the Provincial Regulations.

A paper on the "Preparation of Water for Filtration" was presented by Mr. F. A. Dallyn, in the absence of Mr. A. V. DeLaporte, who was unable to be present.

Discussion of this paper was deferred for a few minutes to permit His Worship Mayor Maguire to address the meeting. Mayor Maguire received a hearty reception when introduced by the Chairman. In extending a welcome to the Association, His Worship commented upon the importance of the utility represented by the gentlemen present. He referred to the improvements and benefits which had come to Toronto through the efforts of engineers and others who were making a life study of the water question. In closing his address he urged all water works men to interest themselves in municipal problems in general and to work for closer interprovincial and international relations.

Mr. Dallyn's paper was here taken up and the discussion which followed held the interest of the whole meeting until the closing hour.

At 8:00 p.m., the members of the Engineer's Institute joined in the discussion of Mr. Norman J. Howard's paper on, "Purification of Public Water Supplies," after which the meeting adjourned to the banquet room where the manufacturers provided entertainment.

On Friday, February 23, at 9:30 a.m., Mr. W. G. Henderson, Chief Accountant of the Peterboro Utilities Commission, gave an illustrated talk on, "Water Works Office Records and Accounting." Mr. Henderson answered questions which brought out many interesting features. Mr. Henderson has discarded the old type of assessment book and ledger and has substituted therefor a card ledger system. His card system also covers maintenance costs, construction costs and service installations.

Mr. A. E. Berry, of the Provincial Board of Health, read a paper on, "Water Chlorination Apparatus and Its Control." Mr. A. H. Burn was present with apparatus to demonstrate the ortho-tolidin test for residual chlorine. The discussion following this paper by Messrs. Dallyn, Gore, Milne, Nasmith and Howard was enlightening and showed the developments which have taken place in the treatment of water with chlorine.

At 1:00 p.m., the Executive held a luncheon at which Committees were appointed to look after the arrangements at Windsor for the Annual Meeting in May.

At 2:30 p.m., Mr. Alexander Milne presented a paper on, "Some Special Water Works Tools and Equipment and Their Use." Mr. Milne's paper was well received and the discussion brought out many interesting experiences of the water works superintendent.

The last paper on the program was on, "The Operation of Gasoline Auxiliary Pumps," by Mr. S. L. Fear, M.E., Montreal. As the auxiliary power plant is an exceedingly important feature, since the introduction of hydro-electric power, Mr. Fear's paper was received with much interest.

This brought to a close the fifth gathering of the Canadian Section. The third annual meeting of the Section will be held in Windsor on May 19 and 21. It has been suggested that the Constitution be so amended as to make the mid-winter meeting the annual meeting, at which the manufacturers' exhibit will become a permanent feature.

ADDITIONS TO MEMBERSHIP

Jeremiah L. Ames, Filtration Division, Porter Avenue Station, Bureau Water, Buffalo, New York.

Richard Ankener, 140 12th Avenue, Long Island City, New York,

R. Fraser Armstrong, Woodstock, New Brunswick, Canada.

Norman Z. Ball, Assistant Engineer, In Charge of Water and Sewers, Norfolk, Virginia.

Geo. W. Bates, City Engineer, Lincoln, Nebraska.

Claude Francis Blain, Public Works Department, Sydney, New South Wales, Australia.

Stephen W. Borden, General Manager, 19 Beechwood Road, Summit, New Jersey.

George H. Bragg, 445 Sutter Street, San Francisco, California.

A. R. Brown, President Erwin Water Company, Erwin, Tennesee.

James W. Coburn, Treasurer Rensselaer Water Company, P. O. Box 868, Portland, Maine.

J. E. Costa, City Hall, Pittsburg, California.

Charles I. Corp, Madison, Wisconsin.

Robert E. Coughlan, Supervisor Water Supply, Chicago and North West Railroad, 109 S. Karlov Avenue, Chicago, Illinois.

J. Franklin Diggs, Jr., Linthicum Heights, Maryland.

R. L. Dobbin, Superintendent Water Works, 253 Hunter Street, Peterborough, Ontario.

Chester G. Ehle, Portland, Oregon.

Louis L. Farrell, 2145 Adeline Street, Oakland, California.

Prof. John N. Finlayson, University of Manitoba, Winnipeg, Canada.

George M. Flint, 14 Beacon Street, Room 613, Boston, Massachusetts.

Walter S. Frick, C.E., East Falls Church, Virginia.

Howard R. Fullerton, Tennesee State Board of Health, 405 Seventh Avenue North, Nashville, Tennessee.

Louis A. Geupel, Room 152, Basement State House, Indianapolis, Indiana.

Mortimer M. Gibbons, 58 Market Street, Poughkeepsie, New York.

A. L. Googins, Sanitary Engineer, 332 Lindenwood, Topeka, Kansas.

H. G. Hall, Ingersoll, Ontario.

C. D. Hays, Huron, South Dakota.

R. W. Hendricks, Chicago, Illinois.

Albert S. Hibbs, Assistant Superintendent, Akron City Water Works, 102 E. Mill Street, Akron, Ohio.

Edgar M. Hoopes, Jr., Wilmington, Delaware.

Tomi Iwasaki, Water Works Department, Suido Kakucho, Tokyo-shiyakusho, Japan.

David Jenkins, Care of The New Jersey Zinc Company, Franklin, New York.

W. T. Jones, Superintendent, Water and Light Department, Lexington, North Carolina.

Hiroynki Kayanski, City Planning Bureau, Department of Home Affairs, Tokio, Japan.

J. Clarke Keith, Windsor, Ontario.

Hugh Kellner, Chief Engineer City Water Works, 74 Moy Avenue, Windsor, Ontario.

William Gray Kirchoffer, Sanitary and Hydraulic Engineers, 22 N. Carroll Street, Madison, Wisconsin.

James E. Lamb, C.P.A., 301 Chestnut Street, Harrisburg, Pennsylvania.

Wilfred F. Langelier, Associate Professor Sanitary Engineering, University of California, Berkeley, California.

Harry N. Lendall, New Brunswick, New Jersey.

Charles Taylor McFarland, M.E., McFarland Engineering Company, 307 Mutual Building, Kansas City, Missouri.

M'Kean Maffitt, Superintendent Water and City Engineer, Wilmington, North Carolina.

Winfield S. Mahlie, Chemist in Charge Filtration Plant, Fort Worth, Texas.

Andrew B. Mauzy, Water Conservator, City Hall, Jersey City, New Jersey.

Geo. A. Meeker, Geneseo, New York.

Maurice L. Miller, Consulting Hydraulic and Sanitary Engineer, 203 Boston Building, Denver, Colorado.

Warren C. Miller, City Engineer, City Hall, St. Thomas, Ontario.

A. J. F. Montabone, Room 2, Imperial Theater Building, Montreal, Canada.

Wallace W. Morehouse, Superintendent Division of Water, 20 E. Second Street, Dayton, Ohio.

Geo. L. Moulton, Charlotte, North Carlonia.

H. P. Musser, Kanawha National Bank Building, Charleston, West Virginia.

Geo. I. Nelson, St. Louis, Missouri.

A. I. Olding, 17 West Seventh Avenue, Redfield, South Dakota.

Noble L. Owings, Assistant Engineer, Washington Suburban Sanitary District, Riverdale, Maryland.

Charles Warren Parsons, Chicago, Illinois.

C. A. Pauly, Chief Engineer, Lorain Water Works, 760 Osborne Avenue, Lorain, Ohio.

A. G. Peirson, Superintendent Water Power and Light Commission, Weston, Ontario.

Asa E. Phillips, 26 Jackson Place, Washington, D. C.

Arthur H. Pratt, Chief Engineer, North Jersey District Water Supply Commission, 20 Clinton Street, Newark, New Jersey.

S. T. Prokofieff, Hydraulic Engineer's Office, Municipal Offices, Bombay, India.

W. E. Quillan, General Manager United Gas and Electric, 16 West Sherman, Hutchinson, Kansas.

Edward J. Reilly, St. Louis, Missouri.

E. A. Rowe, 1104 Central Building, Los Angeles, California.

Daniel H. Rupp, Water Department, Liverpool, Ohio.

George G. Schaut, 925 W. Susquehanna Avenue, Philadelphia, Pennsylvania.

Warren J. Scott, Sanitary Engineer, Extension Division, University of Iowa, Iowa City, Iowa.

Harry B. Shaw, Hyattsville, Maryland.

C. W. Smedberg, Office Engineer, Carolina Engineer Company, Box 752, Wilmington, North Carolina.

T. W. Snell, Salinas, California.

Wm. E. Stanley, care of Pearse, Greeley and Hansen, 39 West Adams Street., Chicago, Illinois.

John A. Strang, C. E., Wallace and Tiernan Company, Room 507, 180 N. Market Street, Chicago, Illinois.

G. F. Stoldt, Superintendent Water Filtration Plant, care of City Power and Water Plant, Jacksonville, Illinois.

A. H. R. Thomas, Superintendent Waterworks, Box 227, New Toronto, Ontario.

E. J. Thomas, Consulting Engineer, Box 613, Minot, North Dakota.

Robert L. Totten, Birmingham, Alabama.

J. S. Trogdon, City Manager, Box 337, Morganton, North Carolina.

Cyril B. Tygert, 165 Home Avenue, Rutherford, New Jersey.

Earle Lytton Waterman, Associate Professor Sanitary Engineering, 104 Engineer Hall, University of Iowa, Iowa City, Iowa.

Howard C. Weller, Eagle Bay, New York.

Chas. C. West, General Manager, Sayre Water Company, Sayre, Pennsylvania.

D. Chas. Williamson, Chief Engineer, New York Continental Jewell Filtration Company, 145 Delevan Avenue, Newark, New Jersey.

I. E. Wilson, Water Commissioner, City Hall, Faribault, Minnesota.

Fred C. Wintermute, C.E., 404 Second National Bank Building, Wilkes Barre, Pennsylvania.

Charles B. Yost, Fort Wayne, Indiana.

Corporate Members

The Bear Gulch Water Company, Menlo Park, California.

Brampton Water Commission, Brampton, Ontario.

Glen Ridge Water Department, Mr. William Dewar, Superintendent, Glen Ridge, New Jersey.

Board of Municipal Works, Winona, Minnesota.

James H. Baker, Village President, Nunda, New York.

Board of Public Works, City of Poughkeepsie, Water Department, Poughkeepsie, New York.

The Water Commissioners, Windsor, Ontario.

Utrechtsche Waterleiding-Maatschappij, Utrecht, 15 Predikheerenkerkhof, Holland.

Associate Members

The American Well Works, Aurora, Illinois.

Chase Metal Works, 236 Grand Street, Waterbury, Connecticut.

Montague Pipe and Steel Company, 803 Hobart Building, San Francisco California.

Ingersoll, Rand Company, 11 Broadway, New York City.

Voorhees Rubber Manufacturing Company, 20–56 Bostwick Avenue, Jersey City, New Jersey.

DEATHS

David Dexter Clark, Consulting Water Supply Engineer, 211 City Hall, Portland, Oregon.

David A. Decrow, Worthington Pump and Machinery Company, 115 Broadway, New York, N. Y.

C. McWilliams, President Roaring Creek Water Company, Shamokin, Pennsylvania.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, **12:** 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to page of the journal.

The Consumer is Sensitive—Handle Him Carefully. O. H. BISSELL. Fire & Water Eng., **71:** 1068, June 14, 1922. Problem of overcoming prejudice and antagonism which exists between consumer and utility. Author makes following points: "There is one broad principle which I think may be applied with good result: Always treat the public with perfect candor, putting forth every effort to gain its confidence. Every consideration within reason should be shown the individual and every effort made to make him feel that you are not only glad to serve him, but that you have his interests at heart. . . . . There are three qualifications necessary, in my experience, in any way successfully to handle the public: Self-control, some knowledge of human nature, and what we may call an instinctive preception of the kind of individual you have to deal with." 4350 words.—*Geo. C. Bunker.*

The Right Kind of Coating for Pipe. WILLIAM R. CONARD. Fire & Water Eng., **71:** 1102, June 21, 1922. Points out difference between coal tar of today and that used by Angus Smith. Lack of definite statements in present standard specifications and possibility of finding some substitute for tar. Several lines of research suggested in order to obtain an impervious coating which will prevent moisture from passing through the pores with the resultant formation of ferrous oxide and tubercles. 3150 words.—*Geo. C. Bunker.*

Why there should be a Service Charge. J. WALTER ACKERMAN. Fire & Water Eng., **71:** 1147, June 28, 1922. (Excerpts from paper read before 13th annual meeting, New York State Conference of Mayors and Other City Officials, Poughkeepsie, N. Y., June 6 to 8.) The service charge principle is slowly but surely receiving general recognition. On the meter rate plan a consumer should always pay a service charge whether or not any water is used because certain expenses accrue. The railroad commission in California ruled as follows: "We have given this matter very extensive and careful consideration and have arrived at the conclusion that the sound basis for establishing these rates is that there should be first a service charge based on the size of the meter which service charge is to be paid by all consumers regardless of the amount of water used." Practically without exception all water works operate in a dual capacity, as a part of the fire fighting equipment of the city; the other to furnish water for domestic and other purposes. First use is

property benefit, and as such, cost of same should be borne by general tax, exactly as in the case of firemen and their equipment and maintenance. An equitable flat rate schedule can not be devised.—*Geo. C. Bunker.*

Put in Mains Suitable for Fire Service. WALDO S. COULTER. Fire & Water Eng., **72:** 127, July 26, 1922. Discussion of use of 4-inch pipe in small-town systems. In most cases the use of such pipe is inadvisable. Although it may be of sufficient capacity to care for immediate requirements, it fails to provide suitable margin for unforseen future increases in consumption or growth of district. Use of this pipe is generally result of economical motives. The economy is more apparent than real. Four-inch pipe should not be considered for three-stream service.—*Geo. C. Bunker.*

How a Big Water Improvement was Financed. HARRY RUTHRAUFF. Fire & Water Eng., **72:** 129, July 26, 1922. Project involving expenditure of over $2,000,000 impounding of over eight billion gallons of water, raising of a steel bridge fifteen feet, and provision of an adequate water supply for Decatur, Ill., allowing for its normal growth for next 50 years. Improvement financed by formation of private company with capital of $1,000,000 from citizens of city, Company, upon completion of payments by city, will surrender water works to it.—*Geo. C. Bunker.*

Water Supply for Town Fire Protection. W. S. RATHBUN. Fire & Water Eng., **72:** 87, July 19, 1922. Detailed discussion of needs of communities with population under 5000. Where normal pressure carried is not sufficient for fire purposes, an automobile fire pumper should be installed. One hundred pounds is maximum pressure satisfactory for domestic service. Records in small towns are generally kept in miserable shape. Careless superintendents carry all records of changes, additions, and repairs in their heads, subject to forgetfulness, until they die or move away. Valves, particularly, should be accurately located so that in case of break quick shut down can be made. Necessity of measuring consumption of water and studying it is emphasized. Deciding factor in organization for care and maintenance of system is the Superintendent. This contains excellent summary of National Fire Underwriters' requirements as to pressures, fire hydrants, sizes of mains, storage, etc.—*Geo. C. Bunker.*

The Wurtemburg District Water Supply. HANNEMANN. Water en Gas, Feb. 17 & March 3, 1922. Abstract in Water & Water Eng. (London), **24:** 308, August, 1922. Supply furnishes water to population of 100,000 in 100 communities (Stuttgart and others). It is taken from ground water in Danube valley, between Langenau and Sontheim. Ground water occurs in gravel and beds at depth of 3 to 12 meters, protected from contamination by overlying bed of clay 3 meters thick. The total output of two groups of 126 wells varies from 650 to 1200 liters per second. Electric driven centrifugal pumps force the water into a pressure main, 900 mm. in diameter and 33 km. long, against a head of 105 to 140 meters. Where the pressure is over 14 atmospheres, the single main is replaced by two mains of 600 mm. diameter. Both cast iron and

steel pipe are used depending upon nature of the ground. The highest point of the conduit consists of a tunnel in the rock forming a reservoir between pressure and gravity conduits, with capacity of 12,000 cu.m. From this reservoir a gravity conduit, 900 mm. in diameter and 60 km. long, with four intermediate reservoirs, each of 600 cu. m. capacity, carries the water to another tunnel-reservoir at end of line from which it flows into the terminal reservoir.—*Geo. C. Bunker.*

New Pump Standards to Increase Efficiency. Fire & Water Eng., **72**: 279, August 9, 1922. Hydraulic Society, composed of principal pump manufacturers of United States recommends standards of manufacture and engineering practice in pump industry. Trade standards as follows: Direct acting single steam pumps; direct acting duplex steam pumps; reciprocating power pumps; centrifugal pumps. Definitions of various terms used in the industry are given.—*Geo. C. Bunker.*

Problems of the Filter Plant Operator. E. J. Rowe. Fire & Water Eng., **72**: 275, August 9, 1922. Problems arising during operation of one-million gallon rapid sand filter plant and changes made to improve operating conditions. Baffling of sedimentation basin changed to reduce depth of deposit at outlet end and amount of silt-like material carried upon filters; period of retention of basin was determined by adding salt solution to alum feed box and determining chlorides in water flowing upon the filters; wave action in basin stopped by extension placed on raw water inlet pipe; method worked out for determining amount of alum applied by dry feed machine; optimum H-ion concentration for floc formation, pH 7.3. Illustrated (Note. More papers like this one from small or large plant operators should be written and published because the experiences and the changes made to improve operating conditions are of great value to other operators. G. C. B.)—*Geo. C. Bunker.*

A Rapid and Accurate Method for the Calibration of Storage Tanks. J. W. M'David. Jour. Soc. Chem. Ind., **41**: 17, 295 T, 1922. Four methods for measuring volume of storage tanks are cited. 1. Measuring tank and calculating volume mathematically (accurate only for tanks of regular shape). 2. Filling tank and weighing the water as it is discharged (laborious). 3. Filling tank with water, adding a definite amount of some soluble chemical, stirring well, and then analyzing sample of known volume (laborious if volume per inch of depth is desired). 4. Depends on principle that water going through an orifice under constant head gives a constant rate of flow. Authors describe apparatus employing this last principle as follows: A brass cylindrical tank 4 inches in diameter, and about 2 feet 1½ inches in length is provided. The tank is open at the top, and is held in a vertical position by means of three legs, each of which carries a levelling screw. A plumb-line is provided to ensure that the apparatus is set vertically. Water is supplied to the apparatus through the ¾-inch inlet cock, to which a hose-pipe can be attached. A brass overflow pipe ¾ inch in diameter is provided while a pipe of similar size delivers water to the tank to be calibrated. The bottom of the delivery pipe is fitted with a screw thread, so as to take a nozzle. Five nozzles of diameters

$\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, and $\frac{3}{4}$ in. respectively were provided, so that the quantity of water delivered to the tank could be varied. A funnel, below the calibrated nozzle, works on a swivel, so that it can be placed underneath the nozzle is an instant, and so divert the water from the tank which is being calibrated. A plate perforated with holes $\frac{1}{4}$ inch in diameter serves the double purpose of forming a support for the overflow and outlet pipes, and at the same time reducing turbulence at the surface of the water. The complete apparatus only weighs 26 pounds, and can therefore be easily carried about from place to place by one person. The instrument is set up in a vertical position over any convenient inlet hole in the cover of the tank to be calibrated. The funnel is placed under the nozzle, and sufficient water led into the apparatus through the cock, until there is just a slight trickle of water escaping through the overflow pipe. In the experiments carried out to calibrate the apparatus the quantity of water escaping through the overflow pipe was determined, and averaged 0.7 to 1.5 pounds per minute. As soon as water is leaving the overflow pipe at the rate mentioned above, the head of water in the apparatus has reached a constant figure, and, so long as this level is maintained, the quantity of water delivered through the nozzle will be constant. When this condition has been obtained the funnel is quickly drawn from below the nozzle, and the water is allowed to flow into the tank. At the same time a reliable stop-watch, is started. If it is required to find merely the total volume of the tank, the time taken to fill it with water is noted, but if it is required to determine the volume per inch of depth, then the funnel is placed beneath the nozzle after a definite interval of time and the depth of water in the tank measured. By choosing suitable intervals of time the volume per inch of depth can be calculated. An accuracy of 0.3 to 0.5 per cent is claimed.—*A. M. Buswell.*

Pollution of Streams Affecting Industrial Uses. J. FREDERICK JACKSON. Jour. N. E. W. W. Assoc., 36: 1, 14, Mar., 1922. Quantity and quality of water required for industrial purposes in Connecticut. Amount of water used industrially about three times that used for domestic purposes. Softness, acidity, organic matter, suspended matter, color, and iron are all constituents which affect industrial processes; but different qualities are required for different industries. Analyses of the Naugatuck River show effect of industrial wastes upon its composition. Results of analyses of wastes from copper and brass, rubber, iron and steel, woolen, paper and silk industries are also given. Efforts of most factories have been towards securing suitable boiler feed water. Savings might be realized by the selection of proper sources of supply or by purification of polluted supplies. Removal of pollution would be beneficial.—*E. S. Chase.*

Manganese Bronze for Valve Stems. WM. R. CONARD. Jour. N. E. W. W. Assoc., 36: 1, 32, Mar., 1922. Early water works valves were provided with wrought iron stems; later brass, or bronze, stems were substituted. One of the best bronzes was the so-called "Government mix," 88 parts copper, 10 parts tin and 2 parts zinc. Still later, rolled bronze was used for its greater strength. Manganese bronze can be produced to meet almost any requirement as to physical properties. Strength of valve stems important Stresses in stem are

tension on body of stem, shear on threads and torsion during opening and closing. Best bronze for stem is one having high elastic limit, moderate ductility, high ultimate strength, but not more than 100 per cent greater than elastic limit. It is possible to secure manganese bronze with an elastic limit of not less than 40,000 pounds per square inch, ultimate strength 60,000 to 70,000 pounds per square inch, 10 per cent elongation in 2 inches and 10 per cent reduction in area. It is important that test pieces be secured to have assurance of quality of metal. For small and medium sized valves up to say 24 inches, cast stems are proper, for 30 inches or larger stems should be of forged manganese bronze.—*E. S. Chase.*

A Rating of the Qualities of the Water Supplies of Massachusetts. GEO. C. WHIPPLE. Jour. N. E. W. W. Assoc., **36**: 1, 40, Mar., 1922. Four major items in rating qualities of water supplies of Massachusetts: sanitary quality, attractiveness, mineral constituents, corrosiveness. Organisms of fecal origin are index of sanitary quality and population per square mile may be regarded as basic measure of dangers at source of supply. Various factors affect degree of danger and it is difficult to express in figures the sanitary hazard. Not average conditions as a rule which produce an epidemic. It is some exceptional combination of conditions, the frequency of occurrence of which it is impossible to compute. Irregularity in character of supply is condition of danger. Purification plants are subject to the fallibility of human element. Massachusetts fortunate in having favorable soil conditions and storage facilities for water supply purposes.

Attractiveness made up of color, clearness, brilliancy, odor, taste, aeration, temperature and aesthetic surroundings of source. For comparisons the per cent of time during which a water supply possesses odors of different degrees of intensity is most useful basis. Massachusetts waters are practically all fairly soft, but iron and manganese give more or less trouble in the case of ground waters.

The corrosiveness of a water related to hydrogen ions. pH determinations should be made of all water supplies throughout the year. Corrosive properties also compared by CO_2, alkalinity, color and chlorine. Diagram is given showing relation between these constituents and corrosiveness. Difficult to classify waters of Massachusetts as to corrosiveness. In general, hard surface waters of western part are but slightly corrosive, while soft surface waters of middle and eastern parts are slightly corrosive. Well more corrosive than surface waters. Lead poisoning less frequent than formerly because less lead pipe is used.

Comparatively few surface waters of Massachusetts are filtered, about 24 filter plants being in use. Water supplies are reasonably satisfactory from sanitary standpoint, but poor physical qualities make filtration of all surface supplies desirable. Furthermore almost every year in the spring some city has an outbreak of a mild type of dysentery which appears due to water supply. Filtration would be a safeguard.

Whipple discusses relative indifference displayed towards water analyses. Attitude of water superintendents indicates an over-confidence in state supervision. Paper concludes with tables giving Massachusetts munici-

palities having public water supplies and analyses of these supplies.—*E. S. Chase.*

Fourth Report on Colloid Chemistry and Its General and Industrial Applications. R. T. SLATER PRICE. Jour. Soc. Chem. Ind., 41: 461. Report issued by Committee of British Association for the Advancement of Science under arrangement with the Department of Scientific and Industrial Research. Similar in plan to three reports already issued. Subject-matter arranged under two heads, (1) classification according to scientific subject; (2) classification according to industrial process. The sections covered are: "Colloid Problems in Analytical Chemistry," by H. Bassett; "Cataphoresis: The Motion of Colloidal Particles in an Electric Field," by E. F. Burton; "Colloid Systems in Solid Crystalline Media," by C. H. Desch; "Molecular Atrraction and the Physical Properties of Liquids," by Edwin Edser; "Membrane Equilibria," by W. E. Garner; "Disperse Systems in Gases," by W. E. Gibbs; "The Theory of Lubrication," by W. B. Hardy; "Application of Colloid Chemistry to Mineralogy and Petrology," by Alex Scott. The technical papers included under the second heading are: "The Colloid Chemistry of Soap. Part II. The Soap Boiling Processes," by J. W. McBain and E. Walls; "The Concentration of Ores by Flotation," by Edwin Edser; "Colloids in Catalytic Hydrogenations," by E. F. Armstrong and T. P. Hilditch; "The Rôle by Colloids in Electrolytic Metal Deposition," by H. J. S. Sand; "Rubber," by H. P. Stevens; "Colloidal Fuels, their Preparation and Properties," by A. E. Dunstan.—*A. M. Buswell.*

Measuring Public Fire Protection. HARRY J. CORCORAN. Proc. Iowa Eng. Soc., 34: 61, 1922. Discussion based on "Standard Schedule for Grading Cities and Towns in the United States," of National Board of Fire Underwriters. The sum of "maximum points of deficiency" is 5000, distributed as follows: Water Supply, 1700; fire department 1500; fire alarm, 500; police, 50;building laws, 250; hazards, 300; structural conditions, 700. In grading the city about 128 separate topics must be considered, of which 66 concern water supply and fire department.—*Jack J. Hinman, Jr.*

Need Better Cost Accounting for Water Softening. W. H. HOBBS. Ry. Rev., 71: 267, 1922. Present method of computing value of water softening in terms of pounds of scale removed should be converted to expression in ton-miles or engine miles.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

St. Paul Adopts Water Treatment on Large Scale. C. HERSCHEL KOYL. Ry. Age, 73: 573, 1922. Ry. Main. Engr., 18: 344, 1922. Installation of fourteen plants results in economical solution of serious operating problems. Two types of construction are used: both continuous and mechanical agitation of Ca $(OH)_2$, Na_2CO_3, and Fe SO_4 for 40 minutes with upflow of water in mixing tank are featured. Comparative analyses before and after treatment, of water containing 95.7 grams per gallon incrusting solids, show efficient results. Plans of installations are given.—*R. C. Bardwell.* (*Courtesy Chem. Absts.*)

Construction of Kettle Creek Dam, St. Thomas. W. C. MILLER AND G. H. CHALMERS. Can. Eng., **42**: 444–7, 1922. Minimum run-off of 6.15 inches for year expected. Storage of 350 million gallons provided. Dam is of earth, with concrete core-wall and concrete spillway.—*Langdon Pearse.*

Motor Driven Centrifugals with Gas Engine Standby. W. B. BUSHNELL. Ill. Sect. Am. W. W. Assn., 1922. Mun. Cty. Eng., **62**: 215–6, 1922. Eng. and Cont., **58**: 48–9, 1922. Champaign and Urbana Water Company has motor driven station with gasoline driven generator (200 K. V. A) to furnish standby current.—*Langdon Pearse.*

Care of Fire Hydrants. D. R. GWINN. Indiana San. & W. S. Assn., 1922. Eng. & Cont., **58**: 49, 1922.

Beach Water Works Pumping Plant at Hamilton. R. DEBRUNO-AUSTIN. Can. Eng., **42**: 462–8, 1922. After general description of pumping machinery in station, details of tests of motor and steam-turbine driven centrifugals are given, handling about 10 million Imperial gallons per 24 hours against total head around 300 feet. Duty of 117.16 million foot gallons per 100 pound of steam was obtained.—*Langdon Pearse.*

The Bacteria Coli Tests. M. F. STEIN. Eng. & Cont., **57**: 445–6, 1922. Relation between positive results in samples of 1 and 10 cc. is discussed mathematically.—*Langdon Pearse.*

Pumping and Filter Plant at Sturgeon Falls, Ont. Can. Eng., **42**: 599–60, 1922. Supply drawn from Sturgeon R. by two 6-inch 2-stage centrifugal pumps and discharged through 3 pressure filters.—*Landgon Pearse.*

Sterilization of Swimming Pool Supplies. J. VON BENSCHOTEN. Can. Eng., **42**: 477, 1922. Recirculating system recommended in preference to fill and draw system, with liquid Cl sterilization.—*Langdon Pearse.*

Columbus Filtration Items. Pub. Works, **52**: 373, 1922. In 1921 Columbus, Ohio softening plant reduced hardness from 269 to 100 p.p.m. Repairs were made to soda ash solution tanks by lining with sheet lead. Stirring machinery has been furnished with new and heavier paddles. Some new sand has been added to filters.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Water-Borne Typhoid in Havre. J. SANARENS. Pub. Works, **52**: 441–2, 1922. Surface pollution quickly reaches water supply drawn from chalk. Typhoid follows rains.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Hetch Hetchy Dam. Pub. Works, **53**: 21–4, 43–5, 1922. Concrete dam is 430 feet high, 298 feet wide on base, 900 feet long. River diverted through rock tunnel by crib dam 40 feet high, 320 feet long. *Langdon Pearse.* (*Courtesy Chem. Abst.*)

Filter Plant Operation at St. Louis. E. E. WALL. Ann. Rep. Water Commr., 1922. Eng. & Cont., **58**: 250, 1922. Cost of filtration $4.44 per million gallons. Rate of filtration from 74.35 to 98.31 million gallons per acre per day. Runs from 11.16 to 237.58 hours, averaging 70.98 hours. Wash water rate changed from 15.7 to 15.0 gallons per square foot per minute. Softening saves city $920 per day in soap.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Comparative Data on Operation of Filter Plants at Reading, Pa. 56 Ann. Rep. Water Bureau, 1920. Eng. & Cont., **58**: 250, 1922. Data on costs at 4 plants given, ranging from $1.63 to $5.08 per million gallons. Comparison is made of 1920 and prewar costs in detail.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Costs of Repairing Meters at Cincinnati, Ohio. Ann. Report Water Dept., 1921. Eng. & Cont., **58**: 250, 1922. Costs are given for 3 years, on sizes from $\frac{5}{8}$ to 6-inch.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Surge Tanks. B. F. JAKOBSEN. Proc. Am. Soc. C. E., April, 1922. Eng. & Cont., **58**: 247–8, 1922. Problem of surge tanks from engineering standpoint. Test data on actual designs are given.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Cost of Water Purification at Cincinnati, Ohio. Ann. Report, Waterworks Dept., 1921. Eng. & Cont., **58**: 246, 1922. Total costs of chemicals, operating and maintenance has increased per million gallons from $3.38 in 1914 to $7.01 in 1921.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Method of Cleansing Mixing Conduits at St. Louis Water Purification Plant. Ann. Rep. Water Commr., 1922. Eng. & Cont., **58**: 123, 1922. A modified disc harrow drawn by cables pulled by horses on the surface has worked successfully in loosening mud and scale.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

A New Method of Rating Water-Bearing Sands and Gravel. W. G. KIRCHOFFER. Pub. Works, **53**: 64–6, 1922. Method suggested is based on Fineness Modulus of Abrams for concrete sands. Analytical data are given.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Enlarging Harrisburg Filtration Plant. Pub. Works, **53**: 77–8, 1922. To the original plant 8 new filters, filter house, head and gate house, sedimentation and coagulating basins, secondary intake for winter, and new pumping units have been added at a cost of $800,000. The filter underdrains are of wrought iron pipe, with $\frac{7}{32}$-inch hole, 3 inches on centers.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Acid Treatment of Wool Scouring Wastes. H. M. LADELL. Mun. Eng. & San. Rec. (England). Pub. Works, **53**: 90, 1922. Acid is added in tanks with 3 times the day flow. 1 gallon acid used per 250 gallons suds.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Laying 36 and 48 inch Water Mains in Stony Ground at New Bedford. W. R. CONARD. Mun. Cty. Eng., **43**: 104–5, 1922. Steam shovel used to excavate average 100 feet of a 6 x 8 foot trench per day. A portable crane on a caterpillar handled pipe. Cost of either machine averaged $38 per day. Seventy-two feet of pipe were laid per day, total cost $26.58 per foot ($15.09 pipe; $11.49 laying and excavation).—*Langdon Pearse.*

Modern Water Filtration Plant at Ashland, Ky. D. H. MAXWELL. Mun. Cty. Eng., **63**: 127–30, 1922. Plant serves 15,000 people with rated capacity of 2.67 million gallons per 24 hours. Work done on cost plus sliding fee bases. Two intakes provided at different levels. Plant includes low lift pumps (2 motor driven, 1 gasoline engine driven) coagulating basins, high service pumps and filters.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

St. Louis Water Works Operation. Ann. Report, 1921–22. Pub. Works, **53**: 102–6, 1922. Encouraging experiments have indicated feasibility of burning pulverized coal. Buying coal on a B.t.u. value and percentage of ash guarantee has proved worth while. New pumping plant being designed to handle 200 million gallons per 24 hours using 1,000 H. P. boiler units and steam between 250 and 300 pounds pressure, with 150 to 200° superheat. New intake proposed to care for fluctuation of 34 feet. In 7 years filter sand has become coated to amount 10 per cent by weight. Settling basins and conduits have been cleaned. For conduits a cable drawn harrow has been very useful.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

New Water Purification and Pumping Plant at Pryor Creek, Oklahoma. L. M. BUSH. Mun. Cty. Eng., **62**: 61–2, 1922. Supplies 300,000 gallons per 24 hours and is electrically driven. The low lift pumps raise water to settling basins, with dry alum feed, the high lift pumps discharging through pressure filters.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Financial Gain from Improving Old Water Systems. L. W. COX. Mun. Cty. Eng., **62**: 62–3, 1922. Data given on a number of Iowa towns on consumption and source of supply. Figures are given to show benefit by increased use if water is purified.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Portable Pipe Thawing Apparatus of Calgary. Electrical World. Eng. & Cont., **58**: 43, 1922.

Shooting Water Supply Wells to Increase their Capacity. W. G. KIRCHOFFER. Mun. Cty. Eng., **63**: 172–4, 1922. Discharge of 20 to 30 pounds of high explosive in deep wells in rock has been found to increase flow.—*Langdon Pearse.*

The Flow of Fluids through Commercial Pipe Lines. R. E. WILSON, W. H. MCADAMS AND M. SELTZER. J. Ind. Eng. Chem., **14**: 105–19, 1922. From Chem. Abst., 16: 1118, Apr. 10, 1922. Large scale experimental study of viscous (straight line) and turbulent flow of liquids through standard steel pipe of 1, 2, and 4 inches in diameter has led to conclusion that all fluids obey

indentically same fundamental laws of flow. Roughness of pipe is comparatively small factor in determining resistance to viscous flow (characteristic of low velocities, small pipes or very viscous liquids) but this is not true of turbulent flow. Results are expressed graphically in 14 diagrams and formulas are given for calculation of turbulent flow and friction factor. Practical problems in liquid and gas flow through pipes can be solved by use of formulas and data in paper.—*R. E. Thompson.*

Simplification of the Indicator Method. L. MICHAELIS. Deut. med. Wochschr., **47**: 465, 1921. From Chem. Abst., **16**: 1101, Apr. 10, 1922. A simple rapid method of determining the H-ion concentration of a liquid is described. The sample under examination, after the addition of m-nitrophenol or p-nitrophenol, is matched with permanent standards prepared from the same indicators and varying concentrations of sodium carbonate. By this method the H-ion concentration of suitable fluid can be determined in 1 minute with an accuracy of $\pm$ 0.05. Directions for conducting test and for preparation of standards are given.—*R. E. Thompson.*

General Colloid Chemistry. IV. The Physical-Chemical Analysis of Aluminium Oxysalts and Aluminium Oxide Sols. M. ADOLPH AND W. PAULI. Kolloid-Z., **29**: 281–7, 1921. From Chem. Abst., **16**: 861. March 20, 1922. Heating an excess of thoroughly washed aluminium hydroxide for a day with hydrochloric acid gave a sol characterized by its inability to pass through parchment paper and by the small amount of electrolyte required to coagulate it. By comparison with the molecular conductivity of such salts as sodium chloride, barium chloride and aluminium chloride, $Al(OH)Cl_2$ was shown to form three ions. The degree of ionization increased rapidly with dilution. The degree of hydrolysis was small, being 0.25 per cent as compared to 4.5 per cent for aluminium chloride at a dilution. V = 1024. Electroendosmotic experiments in a Landsteiner-Pauli apparatus showed both positive and negative aluminium constituents to be present at moderate dilutions, while in very dilute solutions only the positive were present.—*R. E. Thompson.*

Some Electro-Osmotic Experiments with De Haën's Membrane Filters. P. H. PRAUSNITZ. Kolloid-Z., **29**: 293–309, 1921. From Chem. Abst., **16**: 863, March 20. 1922. Experiments on the influence of added electrolytes on electro-osmosis, using de Haën's membrane filters, are described. These filters are particularly suited for such work as their chemical composition (cellulose esters) is uniform and the size of the pores vary according to the number of the filter. The best results were obtained with filters numbered 20 and 320, which have medium sized pores. It was found that the kind and arrangement of the diaphragms, the kind, concentration and reciprocal action of the electrolytes, the adsorption relations of the diaphragms toward the electrolytes, and the presence of colloids or crystalloid nonelectrolytes in the liquids can exert an influence on electro-osmosis.—*R. E. Thompson.*

The Acidity of Mine Waters. F. W. WATSON AND R. A. COOPER. J. Chem. Met. Soc. S. Africa., **22**: 30–2, 1921. From Chem. Abst., **16**: 979, March 20, 1922.

In neutralization tests made on a corrosive mine water containing ferric, ferrous, aluminum, nickel, manganese, magnesium and calcium sulfates, four stages of neutralization were distinguishable. In the first stage ferric iron was precipitated; in the second, aluminum; ferrous iron and nickel together in the third; and magnesium in the fourth. Action of precipitated bases on indicators makes it difficult to obtain satisfactory titration methods for determining completeness of neutralization. Very rapid titration with decinormal sodium hydroxide using rosolic acid indicator gives excellent results in practice. The addition of too large amounts of lime may cause calcium sulfate to crystallize out and obstruct pipe lines and pumps.—*R. E. Thompson.*

Concrete Tank Construction. E. C. SWANSON. Eng. World, **18:** 91–5, 1921. From Chem. Abst., **16:** 998, March 20, 1922. Causes of failure of concrete tanks are discussed. Fundamental requirements for good concrete are: choice of materials, proportioning, mixing, placing and curing.—*R. E. Thompson.*

The Occlusion of Lime by the Ferric Hydroxide Precipitate. A. CHARRIOU. Compt. rend., **173:** 1360–2, 1921. From Chem. Abst., **16:** 1057, Apr. 10, 1922. Occlusion of lime in ferric hydroxide precipitates was investigated and it was found that the quantity of calcium carried down was a function of the concentration of calcium present at the moment of precipitation by ammonium hydroxide, as was found by Torpesco (C. A. 14: 3029). The probable explanation is that there is a tendency for calcium to form an ammonium complex. To prevent the precipitation it is desirable that the solution should be dilute and that the smallest possible excess of ammonium hydroxide be used.—*R. E. Thompson.*

The Phenomena of Layer Formation in Clay Suspensions and their Application to Soil Analysis. E. UNGERER. Kolloidchem. Beihefte, **14:** 63–96, 1921. From Chem. Abst., **16:** 1169, Apr. 20, 1922. Literature is reviewed. In experiments conducted with centrifuged suspensions of ultramarine blue and ultramarine red, observed values regarding size of particles, obtained by counting the number of particles in specimens removed from each layer of the suspension, agreed very well with the values calculated by Stokes equation. Each separate layer indicates particles of definite size. Different strata indicate definite differences in weight and size of particles. Constant temperature conditions influence largely the formation of definite strata of turbidity. Electrolytes, except those with marked coagulating power, do not retard layer formation. Size of particles in fine suspensions can be calculated, with the aid of Stokes equation, from the rate of fall or rise of particles in each layer. Method of counting the particles is described in detail.—*R. E. Thompson.*

Corrosion of Cast Iron in Alkaline Soils. N. W. SMITH AND J. W. SHIPLEY. Engineering, 113- 36, 1922. From Chem. Abst., **16:** 1204, Apr. 20, 1922. Effect of various alkaline substances in soil upon corrosion of cast iron is noted. Methods for prevention of corrosion are given.—*R. E. Thompson.*

Reinigung und Untersuchung des Kesselspeisewassers. (Book). K. SCHMID. From Chem. Abst., **16**: 1290, Apr. 20, 1922.

Electrolysis by Stray Currents. J. CHAPPUIS AND HUBERT-DESPREZ. Compt. rend., **173**: 1344–7, 1921. From Chem. Abst., **16**: 1186, Apr. 20, 1922. The perforations in an underground iron or lead pipe system may be explained as due either to (*a*) electrolytic effect produced by stray currents, in which case the pipe system plays the part of anode; or to (*b*) chemical action due to impurities in the metal, causing a local electric couple. Means to be employed to avoid effect depends on cause, whether (*a*) or (*b*), which can be determined by observation of perforations and products resulting from attack of the metal, and their distribution on the pipes and in the adjacent soil. Experiments showed that electrolysis in soil behaves quite differently than in liquids.—*R. E. Thompson.*

The Radioactivity of the Springs in the Region of Bagnoles-de-l'Orne. P. LOISEL. Compt. rend., **173**: 921–3, 1921; see C. A. 15, 796. From Chem. Abst., **16**: 680, March 10, 1922. Previously reported fluctuations of the Ra Em content of these springs are explained by geological formations. Springs which have constant flow have constant Em content (about 1 millimicrocurie per liter), while those which fluctuate with the rainfall have highest Em content when the flow is greatest.—*R. E. Thompson.*

The Existence of a New Radioactive Emanation in the Springs of Bagnoles-de-l'Orne and the Environment. P. LOISEL. Compt. rend., **173**: 1098 (1921). From Chem. Abst., **16**: 680, March 10, 1922. In studying the gases dissolved in a number of springs a curve of activity was observed which cannot be explained by the existence of any known Em. The period of half life was calculated to be 22 minutes. The name emilium is suggested for this new Em.—*R. E. Thompson.*

Conservation of Water Supplies. Medical Officer, **28**: 2, 16, July 8, 1922. Ministry of Health of Great Britain issued memoranda containing provisions for prevention of waste, for restriction of ordinary consumption, and for supplementing existing supplies.—*A. W. Blohm.* (*Courtesy I. W. M.*)

A Survey of Calcium Hypochlorite Tubes for Use with the Lyster Bag. MAJ. CYRUS B. WOOD. Military Surgeon, **51**: 4, 444, October, 1922. American Expeditionary Forces used one glass ampule containing one gram of calcium hypochlorite, for sterilizing water in 36 gallon Lyster bags. Deterioration of hypochlorite, defective tubes and methods of shipment are discussed in this article.—*A. W. Blohm.* (*Courtesy I. W. W.*)

Relation of Sea-Water to Ground Water along Coasts. JOHN S. BROWN. American Journal of Science, **4**: 22, 274, October, 1922. Detailed information is given of a survey, on the coast of Connecticut, on contamination of shallow and drilled wells, by sea water. Nature of contact between fresh and salt water, and seasonal variation in salt content are gone into.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Uses Old Furnace Linings for Side Wall Construction. JOSEPH HARRINGTON. Power, Jan. 3, 1922. Monolithic furnace walls consisting of ⅝ old fire brick ground and mixed with ⅜ of a high grade, high temperature cement stand up better than original brick, reduce radiation and air filtration and permit operation of the boilers at much higher capacities. Arches constructed with alternate rows of fire brick and the mixture previously described gave similar results. (*A good coating for fire brick furnace walls*, consists of 95 per cent ground fire brick and 5 per cent Portland cement by volume mixed to a plastic state with a 2 per cent solution of sodium silicate. First apply a small surface say about 2 feet square with milk solution of high temperature cement, then trowel surface with the above coating to from ¼ to ½ inch thickness. Abstractor.)—*L. A. Day.*

Recording Pump Efficiency by Thermometric Method. L. BARBILLON AND A. POIRSON. La Houille Blanche, May–June, 1922, p. 84. Water and Water Engineering, **24**: 286, 279, 1922. Calculates loss of efficiency by difference in temperature of water before and after passing the pumps. Claimed to have been successfully used in dets. of turbine efficiency.—*Jack J. Hinman, Jr.*

Lakes of the World. W. HALBFASS. Dr. Petermanns Mitteilungen, Erganzungsheft, No. 185, 169 pp.; Water and Water Eng., **24**: 286, 379, 1922. A list of lakes having an area of over 1 sq. km. giving available data regarding each. Sources of information are noted.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*)

Evaporation and Precipitation on the Earth. DR. GEORG WÜST. Zeitschrift der Gesellschaft für Erdkunde zu Berlin, No. 1–2, 1922; Mo. Weather Rev., **50**: 313–314, 1922. An attempt to sum up the precipitation and evaporation values on land and ocean surfaces and on the earth, using values given by Fritzsche for region from 60°N. lat. to 40°S. lat. and assigning values poleward. Total precipitation on land 112,100 km.³/yr., or 75.3 cm./yr., of which 75,000 km.³/yr., or 50.4 cm./yr., is evaporated and the rest run-off. Total precipitation on ocean 304,200 km.³/yr., or 84 cm./yr., of which 267,100 km.³/yr. or 74.2 cm./yr. is evaporated. Totals for the earth are the sums for land and ocean.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*)

Foot-Layer Densities of Snow. H. F. ALPS. Monthly Weather Review, **50**: 9, 474, September, 1922. In order to test accuracy of Wengler formula that density of any given layer of snow bears a certain relation to density of the top layer, depending upon the depth of given layer below the surface, investigations were made from the fall of 1916 for each season until the spring of 1921 at Summit, California, 40 miles west of Reno, where the average annual snowfall is 442 inches and remarkably uniform in depth. The run-off from snow fields for irrigation and hydroelectric purposes is greater than from any other region in the United States. It was found impossible to determine the density of whole snow cover from density of a layer on surface. This lack of uniformity in density is due to weather conditions. It was proved that snow disappears simultaneously from the top and the bottom. The mean density for

the whole snow cover at Summit, Calif., as determined by the five seasons of investigations is as follows:

DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY
32	34	34	40	49	54

It is believed that the water content of the snow cover at Summit, Calif., and adjacent regions can be determined approximately at any time of the season by applying these average densities to the depth.—*I. W. Mendelsohn.*

Surface Water Supply of Snake River Basin, 1917. U. S. G. S. Water Supply Paper 463. NATHAN C. GROVER, G. C. BALDWIN, G. L. PARKER, F. F. HENSHAW. P. 1–168. **Surface Water Supply of Western Gulf of Mexico Basins, 1918** U. S. G. S. Water Supply Paper 478. N. C. GROVER, GLENN A. GRAY, C E. ELLSWORTH. P. 1–106. **Surface Water Supply of Pacific Basins in Washingto. and Upper Columbia River Basin, 1918.** U. S. G. S. Water Supply Paper 482. NATHAN C. GROVER, G. L. PARKER, W. A. LAMB. P. 1–173. **Surface Water Supply of Lower Columbia River Drainage Basin and Pacific Slope Drainage Basins in Oregon, 1918.** U. S. G. S. Water Supply Paper4 84. NATHAN C. GROVER, F. F. HENSHAW, G. L. PARKER. P. 1–141. Each bulletin contains data for each gaging station in the area noted (for the period of October 1st of the year preceding and up to September 30 of the year of the publication) comprising a description of the station, tables giving results of discharge measurements, the daily discharge of the stream, and monthly and yearly discharge and run-off. Information is included in regard to conditions affecting the permanence of the stage-discharge relation, such as occurrence of ice, use of stream for log driving, shifting of channel, cause and effect of back-water, and diversions decreasing flow at gage.—*Isador W. Mendelsohn.*

Routes to Desert Watering Places in the Lower Gila Region. Arizona. U. S. G. S. Water Supply Paper 490 C. CLYDE P. ROSS. P. 271–315. One of a series of four abbreviated guides consisting essentially of maps, the road logs (which constitute concise guides to watering places), and very brief descriptions of the watering places in desert regions in the United States. In this publication, the area covered lies in central Yuma and western Maricopa Counties, Arizona.—*Isador W. Mendelsohn.*

New York Catskill Mountain Water Supply. A. A. NORTHRUP. Univ. Engr., **35**: 16–23, June, 1922. Brief illustrated popular description of new water supply works for New York City.—(Reprint from Stone & Webster Jour.)—*W. Donaldson.*

Fundamental Properties of Commercial Limes. Part II. M. E. HOLMES, G. J. FINK AND F. C. MATHERS. Chemical and Metallurgical Engineering, **27**: 1212–16, December 20, 1922. Factors affecting settlement of lime. Presents comparative data on a large number of commercial quicklimes and

hydrated limes. With few exceptions, those of the highest available lime contents settled slowest. Freshly slaked calcium limes settled more slowly than mechanically hydrated.—*John R. Baylis.*

Report of the Institute of Hygiene of Water on the Salt Content of the Weser at Breman. K. THUMEN. Mitteil, a.d. Landersanstalt fur Wasserhygiene, 26, 1921, Gesundheits-Ingenieur, March 11, 1922, p. 128, (German), Office International D'Hygiene Publique (French), **14:** 8, 981, August 1922. Permissible limits for chlorine content of water supplies. Chlorine content of 143 mg. per liter produces no taste. Maximum limit of 250 mg. per liter, designated by Public Health Service, considered excessive.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Run-off and Discharge Diagrams. Clay Products Association, Chicago, Illinois, September, 1922. Two diagrams on logarithmic cross section paper, one showing run-off from areas between 10 acres and 100,000 acres, the other showing velocity and discharge from vitrified clay sewer pipe and drain tile from 4 to 42 inch.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Investigations into the Working of a Slow-Filtering Sand-Filter in the Tropics. P. C. FLU. Mededeelingen van den Burgerlijkan Geneeskundigen Dienst in Nederlandsch-Indie. Part 3, p. 135, 1922. Slow-sand filtration, in the tropics, feasible with careful control, but on account of its inability to satisfactorily clarify turbid waters, rapid sand filtration with chlorine or ozone disinfection preferred.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Cost of Pumping Water. Municipal Reference Bureau, University of Kansas, Bulletin 32, 1, June 20, 1922. Compilation of operation statistics for 54 Kansas water works pumping plants. Data on sources of supply, population, consumption, description of pumps and costs of pumping.—*A. W. Blohm.* (*Courtesy I. W. M.*)

The Conservation and Allocation of National Water Resources. P. GRIFFITH. Surveyor, **52:** 1595, 91, Aug. 11, 1922. Lack of interest in water supply questions exhibited by Government and public is strongly criticized. Technical and municipal institutions should combine to arouse interest in subject.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Well and Spring Protection. M. K. SNYDER. Municipal and Sanitary Engineer. Bulletin No. 9, State College of Washington, Pullman, January 1922. Practical means of protecting wells and springs from contamination by sewage and other wastes are discussed.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Water Supply Systems for the Country Home. M. K. SNYDER AND H. J. DANA. Bulletin No. 11, Engineering Experiment Station, State College of Washington, Pullman, July 1922. Drawings showing installations and estimates of cost of different methods available for obtaining water pressure system for country homes.—*A. W. Blohm.* (*Courtesy I. W. M.*)

The Bactericidal Action of Ultra-Violet Light. S. Bayne-Jones, and J. S. Van der Lingen. Johns Hopkins Hospital Bulletin, **34**: 383, 11, January 1923. Methods of determining wave-lengths of light which kill bacteria. Bactericidal action of light is confined to ultra-violet region of spectrum, between 350 $\mu\mu$ and shortest measurable wave-length: 185.6 $\mu\mu$. Limits coincide with absorption of ultra-violet light by bacteria. Temperature coefficient for bactericidal action of light was 1.05 over range of 10°C. Constant μ in Arrhenius formula was 934 to 975. Increase in hydrogen-ion concentration of fluid suspending bacteria during exposure to ultra-violet light increased velocity of bactericidal action. Accelerating effect began at pH 4.6, and was strong in fluids more acid. Neither temperature nor hydrogen-ion concentration rendered bacteria sensitive to longer wave-lengths of light.—*A. W. Blohm.*

Water Treatment Justified by Results Secured. W. C. Smith. Railway Age, **74**: 277, 1922. Mo. Pac. R. R. secures excellent results from 81 water treating plants, making a net annual saving of $500,000. Increased life of flues and fireboxes from use of softened instead of raw water amount to from 100 to 300 per cent; reduction in boiler work from 40 to 75 per cent; reduction in engine failures due to boiler troubles, from 30 to 85 per cent. Outline of organization and method of handling treatment given.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Economies of Water Service for Railway Locomotives. C. H. Koyl. Railway Age, **74**: 275, 1923. Results of water treatment on completely treated engine districts of the C. M. and St. P. R. R., and the Great Northern Railway indicate a saving of $1000 per mile of road or apparently $4000 per engine over costs of operation with the untreated water.—*R. C. Bardwell* (*Courtesy Chem. Abst.*)

The Effect of Polarized Mercury in Locomotive Boilers. Geo. L. Fowler. Railway and Locomotive Engineering, **35**: 10, 1922. Formation of black magnetic oxide of iron on tubes of boilers using Bird Archer Compound is attributed to presence of metallic mercury in compound.—*R. C. Bardwell* (*Courtesy Chem. Abst.*)

The Use of Planktological Methods for the Identification of Pathogenic Bacteria in Water. J. Wilhelmi. Desinfektion, **4**: 81–3, 1922. Wasser u. Abwasser, **17**: 243, 1922. W. proposes the use of plankton nets to remove suspended matter from polluted water, with subsequent examination of shreds of cloth or paper, starch cells or muscular fibers for adhering pathogenic bacteria.—*F. W. Mohlman* (*Courtesy Chem. Abst.*)

Poison Gases and Water Supply. Thiesing. Wasser u. Gas., **12**: 305–9, 1922. Wasser u. Abwasser, **17**: 254, 1922. Mustard gas can be removed from water by boiling ½ hour or by storage for 8 or 9 days at 12°C. Phosgene is quickly decomposed by water. Arsenic compounds are usually associated with hydrocyanic acid and are not removable by boiling. Chlorpicrin, a tear gas,

is insoluble in water. Chemical methods for removal of poison gases are not satisfactory.—*F. W. Mohlman* (*Courtesy Chem. Abst.*)

The Storage of Water Samples before Bacteriological Examination. HAROLD HUSS. Das Gas u. Wasserfach., **15**: 238–9. 1921. Wasser u. Abwasser, 17: 244, 1922. H. claims that Swedish conditions permit an interval of 4 hours between sampling and plating, without icing. If kept under 9°C. the sample may be stored 48 hours, if under 5°C., 72 hours.—*F. W. Mohlman* (*Courtesy Chem. Abst.*)

Some New Sulfonphthalein Indicators (Preliminary Note). BARNETT COHEN. P. H. Reports, **38**: 5, 199. C. substitutes brom cresol green (pH range 4.0–5.6) for methyl red, and adds 4 new indicators to fill gaps in pH series of Clark and Lubs.

SUGGESTED COMMON NAME	COLOR CHANGE	pH RANGE
Meta cresol purple	Red to yellow	0.5–2.5
	Yellow to purple	7.6–9.2
Brom-chlor phenol blue	Yellow to blue	3.2–4.8
Brom cresol green	Yellow to blue-green	4.0–5.6
Chlor phenol red	Yellow to red	5.0–6.6
Brom phenol red	Yellow to red	5.4–7.0

—*Bernard S. Coleman.*

An Experimental Study of the Relation of Hydrogen Ion Concentrations to the Formation of Floc in Alum Solutions. EMERY J. THERIAULT AND W. MANSFIELD CLARK. P. H. Reports, **38**: 5, 181. Description of experiments on rate of floc formation in mixtures of alum solution and alkaline water preceded by brief discussion of equilibria in alum solutions. Authors conclude the following: formation of floc dependent upon pH of final mixture of water and alum; maximum floc precipitation occurs within definite and narrow limits of pH; optimum floc formation in dilute solutions occurs within narrow zone of pH with pH = 5.5 as center; range of pH zone for optimum floc formation is proportional to concentration of salts in the water; the more accurate the pH control the more economical the alum dosage. Authors did not consider influence of color and suspension in the experiments.—*Bernard S. Coleman.*